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Full Name of Author — Nom complet de l'auteur

FRANCIS YIN YEE LAU

Date of Birth — Date de naissance

DEC 13 1955

Country of Birth — Lieu de naissance

HONG KONG

Permanent Address — Résidence fixe

#12 10645-85 AVE. EDMONTON, ALTA
T6E 2K6

Title of Thesis — Titre de la thèse

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Name of Supervisor — Nom du directeur de thèse

DR. CARMICHAEL

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ASPECTS OF COMPUTERIZED INFORMATION SYSTEMS IN CLINICAL MICROBIOLOGY

by

© FRANCIS YIN YEE LAU

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

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(SIGNED) Francis Lau

PERMANENT ADDRESS:

#12 10645-85 Ave

Edmonton, Alta.

T6E 2K6

DATED April 24 1981

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled ASPECTS OF COMPUTERIZED INFORMATION SYSTEMS IN CLINICAL MICROBIOLOGY submitted by FRANCIS YIN YEE LAU in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in MEDICAL BACTERIOLOGY.

J.W. Carmichael

Supervisor

W.K. Hutchison

D. Kenna

James Brunton

Date 21 April 1981

To Helena and Melanie

ABSTRACT

In response to a rapidly increasing workload, many hospital laboratories have turned to automated test methods, and to computer-assisted test requesting and reporting, in order to provide more accurate and efficient service. However, up until now, attempts to computerize the clinical microbiology laboratory have been slowed by the lack of test automation and the greater diversity of results, as compared to biochemistry and hematology.

In this thesis, various computerized microbiology information systems that have been described in literature are summarized and reviewed. Both the benefits and disadvantages of computer information systems for the microbiology laboratory are discussed in detail. A proposal is then made for the development of a computerized information system which is to be implemented at the Microbiology Department of the University of Alberta Hospital in Edmonton, Alberta. This proposal contains all the functional requirements of the Microbiology Department and is to be used as a basis from which further system design and development are to follow. Finally, some areas are presented for future enhancement to the proposed system. Suggestions and cautions are also made to future microbiology computer system developers.

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Table of Contents

Chapter — Page

I. INTRODUCTION 1

A. THE ROLE OF THE COMPUTER IN CLINICAL MICROBIOLOGY 1

B. THE UNIQUENESS OF MICROBIOLOGY REPORTS 4

C. PREVIEW 7

II. GENERAL FEATURES OF COMPUTERIZED INFORMATION SYSTEMS 9

A. TYPES OF SYSTEMS 9

Batch versus On-line Systems 9

Turn-key versus In-house Systems 10

Mini-computer vs Large Central Computer Systems 12

B. SYSTEMS OVERVIEW 12

C. MODES OF DATA INPUT 14

Punch-cards & Paper-tape 14

Mark-sense & Optical-mark Readers 15

On-line Terminals 22

Specialized Terminals 26

Mixed Modes 29

Bar-code & Wand Readers 30

Automatic Reporting of Negative Results 32

D. USE OF WORKSHEETS 33

E. ERROR CHECKING & RESULT VERIFICATION 39

F. PATIENT REPORTS 43

General Remarks 43

Types of Reports 45

Report Format 47
Distribution of Reports 48
G. STATISTICAL REPORTS 55
Laboratory Statistics 56
Antibiotic Susceptibility Profile Reports ...59
Infection Control Reports 63
III. THE MEDLAB MICROBIOLOGY REPORTING SYSTEM AT THE ROYAL ALEXANDRA HOSPITAL: A CASE STUDY 75
A. INTRODUCTION 75
B. MATERIALS & METHODS 77
Computer Equipment 77
Computer Language and Files 77
Input Modes 81
Data Processing 89
Manual Backup System 96
C. RESULTS OF COMPUTERIZATION 97
Departmental Reports 97
Infection Control Reports 100
Patient Inquiry 103
Patient Reports 103
D. DISCUSSION 105
Test Requesting 105
Result Entry 108
Patient Reports 109
Statistical Reports 110
Overall Remarks 111
IV. COMPUTERIZED VS MANUAL INFORMATION SYSTEMS: A COST BENEFIT REVIEW 114

A. COST ASPECTS 114

Cost Comparison Between Computerized & Manual Systems 114

Turn-key vs In-house Systems 117

B. IMPACT OF COMPUTERIZATION IN THE MICROBIOLOGY LABORATORY 121

Major Shortcomings 121

Potential Benefits 123

C. IMPACT OF COMPUTERIZATION ON PATIENT CARE 125

V. A PROPOSAL FOR A COMPUTERIZED MICROBIOLOGY INFORMATION SYSTEM AT THE UNIVERSITY OF ALBERTA HOSPITAL 127

A. INTRODUCTION 127

Background 127

Project Reference 132

B. SUMMARY OF THE PROPOSED SYSTEM 133

Objectives 133

Overall System Requirements 134

C. DETAILED SYSTEM SPECIFICATIONS 137

Guide To System Descriptions 137

Computer Hardware Requirements 139

Proposed Model For Microbiology Specimens & Reports 141

Proposed Model For Serological, Antibiotic Assay Specimens & Reports 163

Data Dictionary 178

Data Base Requirements 185

Computer Procedure Requirements 186

Input/Output Requirements 186

Data Storage Requirements 240

Data Security 245
System Limitations 248
Manual Backup System 248
Constraints & Alternatives 250
D. SUMMARY OF IMPACTS 251
Software Impacts 251
Organizational Impacts 251
Operational Impacts 253
Summary Of Work Flow Improvements 254
E. FORWARD PLANS 255
Strategies For System Development 255
Considerations For Post-Implementation Developments 256
VI. DISCUSSION 258
A. FUTURE DIRECTIONS 258
Computerized Quality Control Assurance 259
Direct Data Acquisition By Computer 260
Interface for Automated Instruments 261
Computer-assisted Laboratory Management 264
B. CONCLUDING REMARKS 264
Adequate Planning 265
Effective Communications 265
Long-term Committment 266
REFERENCES 268

LIST OF PLATES

Plate	Description	Page
1.	Example of the microbiology test request mark-sense card used at the Royal Alexandra Hospital in Edmonton, Alberta	17
2.	Example of the microbiology result entry optical reader document used at the Charing Cross Hospital in England	18
3.	Example of a microbiology result worksheet used at the Foothills Hospital in Calgary, Alberta	35
4.	Examples of the microbiology result workcards used at the Massachusetts General Hospital in Boston	37
5.	Example of the microbiology result entry optical reader document used at the St. Thomas Hospital in England	40
6.	Example of the microbiology test request card used at the Royal Alexandra Hospital in Edmonton, Alberta	84
7.	Example of the microbiology result entry card used at the Royal Alexandra Hospital in Edmonton, Alberta	86
8.	Example of the M.I.C. sensitivity result entry card used at the Royal Alexandra Hospital in Edmonton, Alberta	87
9.	Example of the K.B. sensitivity result entry card used at the Royal Alexandra Hospital	88

LIST OF DIAGRAMS

Diagram	Description	Page
1.	Ideal logical flow diagram for microbiology specimens and reports	140
2.	Proposed domain of change for microbiology specimens and reports	152
3.	Proposed physical system model for microbiology specimens and reports	154
4.	Ideal logical flow diagram for serological, antibiotic assay specimens and reports	162
5.	Proposed domain of change for serological, antibiotic assay specimens and reports	169
6.	Proposed physical system model for serological, antibiotic assay specimens and reports	171

LIST OF FIGURES

Figure	Description	Page
1.	Fundamental differences between laboratories	5
2.	The microbiology test request routine used at the Massachusetts General Hospital in Boston	24
3.	The microbiology result entry routine used at the Massachusetts General Hospital	25
4.	The microbiology test request menu used at the Bexar County Hospital District in Chicago	27
5.	A microbiology result entry menu used at the Bexar County Hospital District	28
6.	A computer-generated discrepancy report used at the Massachusetts General Hospital in Boston	44
7.	A microbiology patient report used at the Baltimore Cancer Research Centre in Baltimore	49
8.	A microbiology patient report used at the Massachusetts General Hospital in Boston	51
9.	A microbiology patient report used at the Shands Teaching Hospital in Florida	53
10.	A microbiology patient report used at the Holy Cross Hospital in Detroit	54
11.	The workload statistics report used in the Meditech microbiology laboratory computer system	57
12.	A microbiology overdue culture summary used in the Meditech microbiology laboratory computer system	58

13. A microbiology positive culture summary used at the Massachusetts General Hospital in Boston.....60

14. A microbiology antibiotic susceptibility profile report, sorted by organisms, used at the University of Alberta Hospital, Edmonton, Alberta.....61

15. A microbiology antibiotic susceptibility proile report, sorted by organisms and specimens/sources, used at the University of Alberta Hospital.....62

16. A computer-generated histogram for comparing the zone sizes of *Staphylococcus aureus* used at the Massachussetts General Hospital in Boston.....64

17. An infection summary report used at the Royal Alexandra Hospital in Edmonton, Alberta.....67

18. A daily epidemiologic report used at the Bexar County Hospital District in Chicago.....68

19. An organism cluster report used at the University of Alberta Hospital in Edmonton, Alberta.....69

20. An infection location analysis report used at the Hartford Hospital in Connecticut.....71

21. A hospital associated infection by organism prevalence report used at the Hartford Hospital in Connecticut.....72

22. A positive microbiology culture per consultant summary report used at the Royal Lancaster Infirmary in England.....74

23. Portion of the body site file used at the Royal Alexandra Hospital in Edmonton, Alberta.....79

24. Portion of the specimen file used at the Royal Alexandra Hospital.....79

25. Portion of the bacteriology nomenclature file used at the Royal Alexandra Hospital.....80

26. Portion of the antibiotic file used at the Royal Alexandra Hospital.....82

27. Examples of microbiology test codes used at the Royal Alexandra Hospital.....82

28. Names of all mark-sense cards used in the Microbiology Department of the Royal Alexandra Hospital.....83

29. Portion of the microbiology test request routine used at the Royal Alexandra Hospital.....90

30. Portion of the result entry routine used at the Royal Alexandra Hospital.....94

31. A bacteriology results print used at the Royal Alexandra Hospital.....98

32. An unverified results print used at the Royal Alexandra Hospital.....99

33. A microbiology department log used at the Royal Alexandra Hospital.....101

34. A microbiology laboratory statistics report used at the Royal Alexandra Hospital.....102

35. A microbiology susceptibility report used at the Royal Alexandra Hospital.....104

36. A microbiology patient summary report used at the Royal Alexandra Hospital.....106

37. Summary of items required in the computer and manual information systems.....116

38. Summary of cost comparison between the production of manual and computer microbiology patient reports.....118

39. A proposed layout of the collection labels.....179

40. From a to s, microbiology specimen and test request menus.....188

41. From a to q, microbiology result entry menus.....199

42. A proposed layout of the check-in list.....213

43. A proposed layout of the overdue list.....215

44. A proposed layout of the positive culture summary list.....217

45. A proposed layout of the referral list.....219

46. A proposed layout of the reject summary list.....221

47. A proposed layout of the result summary list.....223

48. A proposed layout of the verify list.....225

49. A proposed layout of the worklist.....227

50. A proposed layout of the infection summary report.....229

51. A proposed layout of the patient's cumulative report.....231

52. A proposed layout of the patient inquiry report.....233

53. A proposed layout of the patient's daily report.....235

54. A proposed layout of the specimen tally report.....237

55. A proposed layout of the susceptibility profile report.....239

56. A breakdown of microbiology test procedures performed by the Microbiology Department of U. of A. Hospital during 1977 to 1979.....241

57. Actual number of referral specimens sent to Provincial Laboratory by the Microbiology Department during a six month period between 1979 and 1980.....242

58. Summary of length of time required to complete a test for each type of microbiology test procedure at the University Hospital.....243

59. A proposed security system for data access at the Microbiology Department of the University Hospital.....246

60. A proposed authority level requirement for each computer procedure in the Microbiology Department at University Hospital.....247

I. INTRODUCTION

A. THE ROLE OF THE COMPUTER IN CLINICAL MICROBIOLOGY

During the last decade or so, most clinical microbiology laboratories have experienced a dramatic increase in the demand for routine and special investigations. Consequently, the massive volume of workload has given rise to many problems, mainly in the organization of workflow within the laboratory, the generation and distribution of patient reports to doctors, the clerical aspects of filing and retrieval of patient test results, and finally in the review and evaluation of the large amount of patient data.

The computer, because of its abilities to process and store a large number of records, to carry out repetitious calculations at a very high speed, and also to make logical decisions based upon a set of pre-defined parameters, appears to be the ideal solution to these problems. Together with the recent advancement in computer technology, which has reduced dramatically the cost of computer hardware, more and more clinical microbiology laboratories have begun to take advantage of this technology by either installing commercial 'turn-key' systems or developing their own customized systems.

However, the application of the computer to routine diagnostic service in clinical microbiology has so far been limited in comparison to other laboratory disciplines such

as chemistry and hematology. This is mainly due to the highly automated routines and the numeric nature of the results in these areas, which are well-suited for computerization. In contrast, the lack of automation, and complexity in the routine determinations and reporting of microbiology results have presented greater difficulties and challenges in the development of adequate programs.

Early attempts to computerize clinical microbiology laboratories were reported by Whitby (1972), Spraberry (1969), and a few others (Harvey 1970, Alexander 1970). All of the systems described were batch-oriented systems that used either punched-cards or paper-tape (the only methods that were available at that time). Besides generating patient reports, these systems were also able to produce some workload census, and limited statistical reports such as the antibiotic susceptibility profiles. There were also other systems described that centred on either infection control surveillance or antibiotic susceptibility profile monitoring (O'Brien 1969, Reed 1970, Schneierson 1967, Steinhauer 1967). Despite their cumbersome methods of data collection and entry, they were claimed to be adequate for the intended purposes.

As the state of the computer technology became more advanced, newer systems using mark-sense cards (Lupovitch 1979, Lau 1979, Ayliffe 1973), optical mark reader documents (Andrews 1974, Bergqvist 1975, Williams 1978), and on-line cathode-ray-tube (CRT) terminals (Brun 1979, Kobernick 1979,

Lo 1976, Jorgensen 1978) were developed and described in literature. These systems offer additional features - cumulative patient reports, administrative reports, overdue report summaries, and control routines for error checking. Most important of all, the emergence of these on-line systems has allowed patient data to be accessible immediately thus eliminating many of the problems associated with result retrieval.

Clearly, there are many potential computer applications that can serve the microbiology laboratory. These are best summarized by Kunz[1] to be as follows:

1. Classification and identification of micro-organisms isolated from clinical sources.
2. Assistance in fiscal and other administrative housekeeping operations of the laboratory.
3. Reporting of laboratory results to patients' hospital records.
4. Detection of errors and control of quality of performance and of similar technological activities.
5. Analysis of antibiotic susceptibility test results and of similar data.
6. Assistance in epidemiological studies and control of nosocomial infections.
7. Teaching, retraining and testing of personnel.

Unfortunately, up till now, the magnitude of change in clinical microbiology has not been as drastic as in most other laboratory disciplines. At present, there still isn't a single system documented that is capable of performing all

---

[1] Quoted from page 170 of 'Computerization in microbiology' in Human Pathology vol.7, no.2, pg.169-175, March. 1976.

of the desired functions mentioned by Kunz. However, with the continuing dedicated efforts of microbiologists and computing experts working together, it is probable that such systems will eventually be achieved. The role of the computer in clinical microbiology will undoubtedly continue to be the centre of great attention for the years to come.

B. THE UNIQUENESS OF MICROBIOLOGY REPORTS

The microbiology laboratory differs from most other laboratory disciplines in the nature of the tests that are performed and the types of results that are produced. For example, in clinical chemistry, the workflow pattern is mostly parallel, that is, several tests are usually carried out at the same time on the same specimen with one or more instruments, and the results that are generated are always numeric. Whereas, in microbiology, the work flow is always sequential, starting with recording the appearance of the specimen, culturing the specimen and then isolation of the organisms, and performance of various identification and antibiotic susceptibility tests, etc. Also, the results that are generated are mainly descriptive rather than quantitative. These differences are summarized in figure 1.

Other major differences include the format and the frequency of production of patient reports. In contrast to the single quantitative numeric result that appears on a chemistry report, a typical microbiology report usually contains a description of the appearance on direct

	CHEMISTRY	HEMATOLOGY	MICROBIOLOGY
WORKFLOW	parallel	sequential & parallel	sequential
TYPE OF RESULTS	numbers	words and numbers	words

Figure 1. Fundamental differences between laboratories are listed here. Quoted from page 140 of 'Some methods used for evaluation of laboratory computer systems at Charing Cross Hospital' by T.J.R. Benson in 'Computing in clinical laboratories' edited by F. Siemaszko 1978. By Pitman Medical Publishing Co. Ltd.

microscopic examination, one or more organism names with the corresponding antibiotic susceptibility profiles, and occasionally one or more comments. Also, instead of the proceeding from a 'pending' status to obtaining and reporting the final result in a one-step process, as in chemistry, the reporting of microbiology results is further complicated by the fact that there is usually a preliminary report which is later followed by one or more interim reports as more information is collected from the tests performed in order to identify the organisms. This process may continue for a period of time before the final report can be issued. This lag can vary from a few days to a few weeks or even longer depending on the type of culture requested.

In addition, a single microbiology report has only a limited value, because it is more important for the physician to compare the report with previous reports in order to monitor any changes in the patient's clinical condition. This is especially important, for example, in the management of cystic fibrosis patients where the respiratory microbial flora require constant monitoring.

Finally, it should also be mentioned that one of the additional roles of the microbiology laboratory is to monitor closely the pathogens that are isolated in the hospital so as to detect any shifts in their antibiotic susceptibility patterns. Any unusual prevalence of an organism in some area of the hospital may be of

epidemiological significance, and must be detected promptly so the physicians can be notified and appropriate control measures taken.

Therefore, when assessing or designing a computerized information system for the clinical microbiology laboratory, one must take into consideration: the non-numeric nature of the results, the variations in the test period, the need to update results and to produce cumulative reports, and the need to produce various statistical analyses.

C. PREVIEW

The purpose of this report is to review various aspects of the computerized microbiology information systems that are available, and to propose an ideal computerized information system that is to be developed and implemented in the microbiology department of a large university teaching hospital centre.

Part II of this report describes some of the characteristics of various computerized information systems. These include a review on the system organizations, input modes, data processing, and the range of reports that can be generated from such systems.

Part III is a description and evaluation of a microbiology reporting system that is part of the Medlab laboratory computer system currently used at the Royal Alexandra Hospital in Edmonton. The evaluation includes an introduction and a brief review of the design, data

processing, and various outputs of the system. Also included are a discussion of some of the problems associated with the system, and the suggested remedies for these problems.

Part IV outlines some of the cost-effectiveness issues associated with computerized microbiology information systems. Various advantages and disadvantages of computerization as expressed by various authors who have had experience in this area are also presented briefly in order to gain some perspectives on the impact of computerization in patient care, as well as in the organization and the operation of the clinical microbiology laboratory.

Part V is a proposal for a computerized information system to be approved and developed for the Microbiology Department at the University of Alberta Hospital in Edmonton. The proposal includes a brief summary of the problems within the existing manual reporting system in the department, and the system requirements, or functional specifications, that are required for the design and development of the proposed system, and the various anticipated impacts it will have in the area of patient care and the organization of the department following computerization. Some provisions for future expansion of the proposed system are also included.

Finally, in Part VI, some general aspects of computer information systems for the microbiology laboratory are discussed.

II. GENERAL FEATURES OF COMPUTERIZED INFORMATION SYSTEMS

A. TYPES OF SYSTEMS

A variety of computerized microbiology information systems have been described in the literature. In general, one can categorize them in several ways, either according to the mode of usage, the nature of the software, or the type of hardware involved. These are briefly summarized as follows:

Batch versus On-line Systems

Most of the earlier systems that have been described are batch-oriented systems that use either punched cards and/or paper-tape as their mode of input. The data processing equipment used is usually rented through some commercial computing service bureaus located outside the hospitals. Examples of these systems include the ones described by Whitby (1970), Spraberry (1969), and Harvey (1972). In these systems, results are usually first recorded on worksheets, which are then coded and keypunched onto the punch-cards and/or paper-tape. These cards and/or paper-tape are then collected and processed in batches through the card/tape readers two or three times daily. The output, which usually consists of the patient reports, error listings, and results summaries, etc., would then be returned to the laboratory, later the same day, for correction and verification. The result summaries are mainly used to answer any patient inquiries received in the

laboratory. Permanent storage of these records varies from simply retaining the punched cards (Vermeulen 1972) to transcribing the data onto magnetic tapes (Spraberry 1969).

As the state of the computer technology continues to evolve and the cost of computer hardware decreases, many hospitals are turning to in-house computer equipment and to on-line systems where constant dialogue between the user and the computer is possible through the use of CRT's or on-line card/document scanners, etc. (Brun 1979, Jorgensen 1978, Kunz 1976). Although in most cases results are still recorded on worksheets and coded before they are entered, most errors can now be detected and corrected immediately upon entry. Most important of all, patient records can now be stored on-line for the duration of the patient's hospital stay. This permits instant report retrieval via on-line terminals.

Turn-key versus In-house Systems

In recent years, there are an increasing number and variety of so-called 'turn-key' laboratory computer systems that are offered by commercial computer vendors. Examples include the Pathlab-1700 series laboratory system from Medlab Co., the LIS-100 series laboratory information system from Lambda Biosystem Inc., and the LDM-8200 series laboratory data management system from Technicon T & T Corporation, etc. These are all dedicated on-line laboratory computer systems that consist of both the necessary hardware and software. The software components usually include

various packaged-programs for clinical chemistry, hematology, blood bank, and microbiology, etc., that can be optional and may be purchased separately.

In general, these commercial 'turn-key' systems are gaining popularity, especially in areas such as clinical chemistry and hematology, because in most cases they are well-developed for these areas and can be implemented quite easily. However, most of the microbiology packages usually represent a novice attempt and have not been too successful in fulfilling the requirements of the clinical microbiology laboratories.

A few in-house, on-line microbiology systems have also been described in recent literature. These are systems that have been designed especially for the particular laboratory involved and are usually developed either by the computing service department within the hospital or contracted through commercial consulting firms. The main advantage of these systems is that they have been claimed to be able to meet the particular laboratory's needs. Examples of these systems include the ones described by Kunz (1976), Lupovitch (1979), and Jorgensen (1978). However, in most cases the development requires tremendous efforts and committment on the part of the laboratory staff, and in addition, are limited only to those that are adventurous and have adequate resources such as the much-needed computer expertise and sufficient funding.

Mini-computer vs Large Central Computer Systems

One can also distinguish laboratory computer systems on the basis of the type of hardware involved. Nowadays, many of the systems described use mini-computers that are dedicated to the processing of laboratory information only. Most of these systems are 'turn-key' laboratory systems supplied by commercial vendors.

Another approach is to have a large central computer within the hospital that can be shared among many departments. The main characteristic of the microbiology sub-system in this type of setup is that it can interact directly with the central computer without any interfaces that are required with mini-computers. Usually these central computer systems are to be expanded to become centralized hospital information systems. Examples of this type of system include the microbiology sub-systems at the Hopital Cardiologique in France described by Brun (1979) and at the Bexas County Hospital District in Chicago described by Jorgensen (1978).

B. SYSTEMS OVERVIEW

Most of the systems described have explicit purposes and well-defined functions. Most commonly these include the following:

1. Test requesting and printing adhesive ID-labels.
2. Accepting test results.
3. Assisting in the verification of test results to ensure

their accuracy.

4. Printing patient reports for doctors.
5. Printing statistical reports for department-heads and administrative staff.

Despite the fact that there are many types of systems available, they are similar in that most of the possible microbiology results to be reported are stored in some form of pre-defined data files, or reference tables. These include the files that store most of the organism terminologies, gram smear phrases, and comments used in reporting; and files that store most of the specimen types and body sites. Each of these pre-defined result phrases is usually referenced by a unique code, which can be numeric, alphabetic, alphanumeric, or mnemonic in nature.

Most important of all, there is always a record for each patient in the system for storing all the test data for each patient. In the earlier systems, a separate patient record is usually created each time a test is requested and there is no linkage between these records for the same patient. In more sophisticated systems there is usually a master record set up for each patient. This record would contain all the demographic data on the patient and is identified by a unique hospital ID number. Each test that is requested would result in the automatic creation of a unique test record which is linked by some means to the master record. These test records usually contain the codes of the results that are entered. Most patient records are usually

retained on-line for a period of time for instant retrieval, after which they would be purged onto some form of storage medium, such as magnetic tapes, for permanent storage.

C. MODES OF DATA INPUT

The following sections serve to outline some of the data entry techniques that are available and describe briefly the characteristics, operations, advantages and disadvantages of each technique.

Punch-cards & Paper-tape

Some of the earliest techniques used data transcribed into codes and keypunched onto punch-cards and/or paper-tape which would then serve as the input to the computer. Data input on these cards or tape is usually of a fixed format with little free-text capability. Two or three times daily these punched cards and tape would be collected and processed in batches. For example, the punch-card systems described by Spraberry (1969) and Whitby (1972) both use a deck of pre-printed patient identification master punch-cards that contains the patient name, ID number, age, sex, location, etc., which is generated by a card punch upon the admission of each patient and is kept on the nursing station. Each time a test is requested one of these master punch-cards is sent along with the specimen and the request to provide the patient information. Once in the laboratory the specimen is assigned an accession number and given a set of workcards and result cards. The accession number is also

punched onto these cards for identification. Results are first recorded on the workcards, which are then coded numerically and keypunched onto the result cards. More than one organism may be recorded on the workcard but only one organism can be punched onto each result card. Therefore, if more than one organism is isolated, additional result cards are required. These result cards, together with the patient master punch-card, then form a pack and can be batched together with other result packs to be processed.

In systems that use paper-tape (Farrar 1975, Gaya 1976, Harvey 1972), requests are usually submitted on conventional request forms with the specimens. The patient information, along with the results, is then coded accordingly and keypunched onto paper-tape. The paper-tape is then collected several times a day for processing.

These techniques are not commonly used at present because they are cumbersome, and in many cases errors cannot be easily detected. However, both Goodwin (1976) and Mitchison (1978), who have recently reported the use of these techniques, have claimed that these data entry modes are still probably the cheapest modes available in terms of the overall capital and operating costs in comparison to the various on-line data entry modes that are described elsewhere.

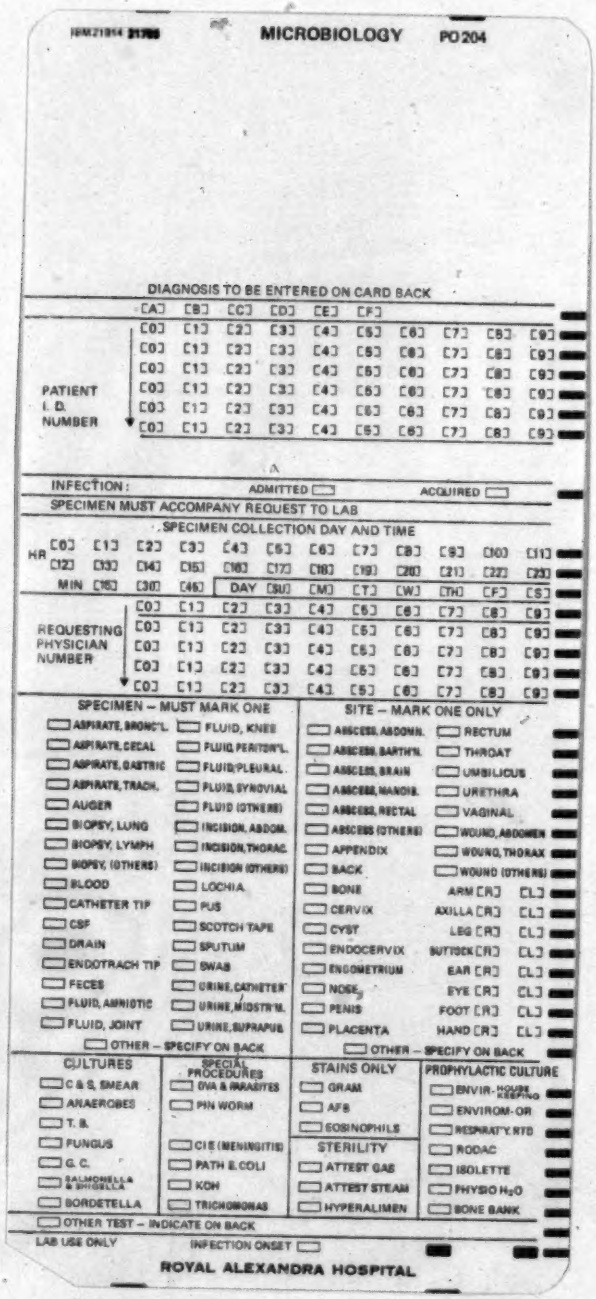
Mark-sense & Optical-mark Readers

Both mark-sense cards and optical-reader documents have been used to process microbiology data. These cards and

documents usually contain an array of labeled boxes and have been programmed so that when a particular box is marked and processed through the reader, a specific function or result as indicated by the label besides the box would be generated in the patient's record. This could either be the initiaion of a test request for a particular patient, or the generation of a result phrase in the patient's record, depending on the type of card or document used. Examples of a mark-sense card and an optical-mark reader document are shown in plates 1 and 2, respectively.

Bergqvist (1975) has described a system that uses optical-mark reader documents for the entry of all microbiology results. In this system, patient information from conventional request form is punched onto cards and processed to be stored on disk. Results, including microscopic examination, organism names, sensitivities and comments, etc., are marked at the appropriate boxes on the document and processed through the reader where they are merged with the patient data that are on disk. Narrative results such as comments can be entered by punch-cards.

In addition to accepting marked cards, some card readers can also process combined marked and punched cards. For example, the susceptibility profile program described by Amsterdam (1969) uses a combined marked and punched card in which susceptibility results are marked at the appropriate boxes on the right side of the card whereas patient information is punched onto the blank space on the left.



MICROBIOLOGY PO 204

DIAGNOSIS TO BE ENTERED ON CARD BACK

[A] [B] [C] [D] [E] [F]

PATIENT I. D. NUMBER

INFECTION: ADMITTED ACQUIRED

SPECIMEN MUST ACCOMPANY REQUEST TO LAB

SPECIMEN COLLECTION DAY AND TIME

HR [0] [1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16] [17] [18] [19] [20] [21] [22] [23]

MIN [15] [30] [45] DAY [SU] [M] [T] [W] [TH] [F] [S]

REQUESTING PHYSICIAN NUMBER

SPECIMEN – MUST MARK ONE

- ASPIRATE, BRONC'L.
- ASPIRATE, CECAL
- ASPIRATE, GASTRIC
- ASPIRATE, TRACH.
- AUGER
- BIOPSY, LUNG
- BIOPSY, LYMPH
- BIOPSY, (OTHERS)
- BLOOD
- CATHETER TIP
- CSF
- DRAIN
- ENDOTRACH TIP
- FECES
- FLUID, AMNIOTIC
- FLUID, JOINT
- FLUID, KNEE
- FLUID, PERITON'L.
- FLUID, PLEURAL
- FLUID, SYNOVIAL
- FLUID (OTHERS)
- INCISION, ABDOM.
- INCISION, THORAC.
- INCISION (OTHERS)
- LOCHIA
- PUS
- SCOTCH TAPE
- SPUTUM
- SWAB
- URINE, CATHETER
- URINE, MIDSTR'M.
- URINE, SUPRAPUB.
- OTHER – SPECIFY ON BACK

SITE – MARK ONE ONLY

- ABSCESS, ABDOMN.
- ABSCESS, BARTH'N.
- ABSCESS, BRAIN
- ABSCESS, MANDIB.
- ABSCESS, RECTAL
- ABSCESS (OTHERS)
- APPENDIX
- BACK
- BONE
- CERVIX
- CYST
- ENDOCERVIX
- ENDOMETRIUM
- NOSE
- PENIS
- PLACENTA
- RECTUM
- THROAT
- UMBILICUS
- URETHRA
- VAGINAL
- WOUND, ABDOMEN
- WOUND, THORAX
- WOUND (OTHERS)
- ARM [R] [L]
- AXILLA [R] [L]
- LEG [R] [L]
- BUTTOCK [R] [L]
- EAR [R] [L]
- EYE [R] [L]
- FOOT [R] [L]
- HAND [R] [L]
- OTHER – SPECIFY ON BACK

CULTURES

- C & S, SMEAR
- ANAEROBES
- T. B.
- FUNGUS
- G. C.
- SALMONELLA & SHIGELLA
- BORDETELLA

SPECIAL PROCEDURES

- OVA & PARASITES
- PIN WORM
- CIE (MENINGITIS)
- PATH E.COLI
- KOH
- TRICHOMONAS

STAINS ONLY

- GRAM
- AFB
- EOSINOPHILS

STERILITY

- ATTEST GAS
- ATTEST STEAM
- HYPERALIMEN

PROPHYLACTIC CULTURE

- ENVIR-HOUSE
- ENVIROM-OR
- RESPIRAT'Y RTD
- RODAC
- ISOLETTE
- PHYSIO H_2O
- BONE BANK

OTHER TEST – INDICATE ON BACK

LAB USE ONLY INFECTION ONSET

ROYAL ALEXANDRA HOSPITAL

Plate 1. An example of the microbiology test request mark-sense card used at the Royal Alexandra Hospital in Edmonton, Alberta.

Plate 2. An example of the microbiology result entry optical reader document used at the Charing Cross Hospital in England.

Mark cells thus: ▬ joining marking aids

Delete mark in error thus: ▬

Do NOT make notes inside the thick red rules.

43571 0

ROUTINE BACTERIOLOGY WORK SHEET

Please use a black felt tip pen.

APPEARANCE AND MICROSCOPY

CULTURE CODE

ORGANISM(S) ISOLATED

SENSITIVITIES

BIOCHEMICAL REACTIONS

SHAPE	LACTOSE
MOTILITY	MacC
GROWTH IN AIR	MALONATES
ADONITOL	MALTOSE
ARABINOSE	MANNITOL
CATALASE	MR
CELLOBIOSE	VP
CITRATE	NITRATE
DECARBOXYL A	OXIDASE
L	PPA
O	RAFFINOSE
GLUCONATE	RHAMNOSE
GLUCOSE (A)	SALICIN
(G)	STARCH
GLYCEROL	SUCROSE
H/L	TREHALOSE
H_2S	UREASE
INDOLE	XYLOSE
INOSITOL	DULCITOL

OTHER ANTIBIOTIC:

COMMENTS TO BE KEYED IN

An actual OMR document used at the Charring Cross Hospital

Ayliffe (1973) has also described a system where a set of mark-sense cards, which consists of a patient identification card, several work cards and a result card, is prepared from each request that is received. Patient information is punched onto the patient ID card, whereas the accession number is punched onto the remaining cards for identification. Results, including the types of media used, microscopic examination, organism names, sensitivities and comments, etc., are marked at the appropriate boxes on the cards. Narrative results can be punched onto a punch-card and processed as free-text comments. Two times daily these cards are collected and processed through a mark-sense reproducer which converts the mark-sense positions into holes. They are then processed as punched cards through the card reader.

There are many advantages in using machine-readable cards and documents. These are briefly summarized as follows:

1. Data on cards and documents are man-readable as well as machine-readable, so one can observe the results that have been entered.
2. In some systems, such as the one described by Bergqvist (1975), no special codings have to be learned by the technologist because each box on the document has been labeled indicating the result that would be generated from the corresponding box.
3. Technologists are not terminal-bound, that is, after

stacking the cards or documents in batches into the optical readers, they can proceed to perform other tasks while these cards and sheets are processed through the readers.

4. With on-line readers, the system can be programmed so that certain errors can cause the cards or documents to be rejected immediately with the corresponding error messages displayed on printer, so any rejected cards or documents can be corrected and reprocessed.
5. Results can still be obtainable on these cards or documents in case of computer failure. They can also serve as permanent records in the laboratory.

There are also some disadvantages associated with this entry mode. These include the following:

1. Patient and request data would have to be recorded on cards and documents for identification purposes by some means. Most commonly these are manually marked at the appropriate boxes on the cards and documents. This has proven to be a somewhat inefficient and error-prone method of data entry.
2. Only a limited number of results can appear on these cards and documents. This imposes rigidity. Results that are not on the card or document cannot be processed.
3. Marking of boxes on cards and documents is critical. Mechanical readers may not pick up poorly-filled boxes, or they may pick up incompletely-erased markings, thus causing errors. Since in some cases it is not possible

to say for certain whether a result has been picked up or not, one would have to check the reports against the original documents or cards. The incidence of mis-read results has been reported to be quite low by Williams (1978) using optical-mark readers, but Gaya (1976) has claimed it to be as high as 7% of all documents processed.

4. The initial cost of these readers is substantially higher than the other data entry modes. They also require frequent maintenance.
5. Even though nowadays most scanners and readers are on-line instruments that allow immediate error detection and rejection, in most cases, the correction of these errors cannot be made immediately. Instead, one would have to retrieve the rejected card or document, make the necessary corrections, and reprocess it at later time.

On-line Terminals

With the emergence of on-line systems, many have turned to the use of interactive terminals such as cathode-ray-tubes (CRTs) and teletype printers for data entry. CRTs are claimed to be better than teletype printers in that their response is usually much faster and quieter. With CRTs one also has the options of using either the keyboard or a light probe or wand reader to enter data.

In general, the data entry routines may either be of a conversational or menu-selection mode. With the conversational mode, the computer would prompt with

questions, one at a time, and wait for input from the user, which is usually in coded form. An example of this mode of data entry is the microbiology system used at the Massachusetts General Hospital decribed by Kunz (1976) in which the initiaion of any programs would cause the computer to generate a series of questions that require inputs from users. Most of the input are in mnemonic codes although the system also has the added capability of processing free-text. All data entries are displayed immediately upon entry for validation. Examples of the request routine and the result entry routine are shown in figures 2 and 3, respectively.

With the menu-selection mode, various menus consisting of input choices are displayed on the terminal for selection. One could either use a light probe to indicate the desired input choices or simply enter the appropriate choices via the keyboard. An example is the microbiology system described by Jorgensen (1978) in which most of the common specimen types and test requests are included in a menu for selection. Any specimen types that are not included in the menu can be entered as free-text up to 12 characters in length. There are also fifteen test result menus that contain the most frequent responses for the most common types of specimens. These include menus for reports on bloods, CSFs, throat & nasopharyngeal specimens, exudates, etc. When the organism name is not among the choices on the menu one can enter the code of the organism according to the

02/17 1945 UNUSED SN: 1945
INITIALS: E
1945

UN 392837 SYKE FW
T SP,C,
1946

UN 483726 DICKENS WH6
T U,C,
1947

UN 584732 DENVER BF3
T FL-CSF,C$,
1948

Figure 2. Portion of the specimen loggin routine used at the Massachusetts General Hospital is shown here. Manually typed material has been underlined to differentiate it from computer-generated typing. Explanatory notes: 1945, 1946, etc., specimen numbers; UN, unit number; T, test; 6 digit numbers, patient numbers; EW,WH6, etc., patient care areas. Quoted from page 184 of 'Role of computer in microbiology' by L. Kunz. et.al. In 'Modern methods in medical microbiology - systems and trends' edited by J.E. Prier, J. Bartola, H. Friedman. 1976, University Park Press.

UN/SN 6571-74 SIMONSON

02/26 U SN: 6571
C
ORG/CH: 1044522 FC CHECK VERY RARE CODE: Y AMT: F CM/S: _

ORG: 5044562 FC AMT: V CM/S: _

ORG: FINAL

UN/SN 6690-37 STEVENSON

02/26 CVS SN: 6690
F STAPH
ORG/CH: EPITH AMT: F CM/S: _
V G-R
ORG/CH: 5044572 FC AMT: F CM/S: _

ORG: FINAL

Figure 3. "Example of dialogue format for entering final culture results into computer. Manually entered data has been underlined to differentiate it from computer-generated printout. Underlined blank spaces signify that an escape Key had been depressed to verify and enter preceding typed data or to escape to next computer-generated word." Quoted from page 186 of 'Role of the computer in by L. Kunz, et. al. In 'Modern methods in medical microbiology - systems and trends' edited by J.E. Prier, et. al. 1976. Published by University Park Press Inc.

master organism code listing that is readily available. Examples of the test request menu and one of the result menus are shown in figures 4 and 5, respectively.

The main advantage of using interactive terminals for data entry is that they allow data to be displayed immediately upon entry for correction and verification. Interactive terminals are also flexible devices because they can be used to enter data as well as to retrieve information stored in the computer system. With the cost of computer hardware constantly decreasing, these devices have also become relatively inexpensive in comparison to the optical scanners and require much less maintenance.

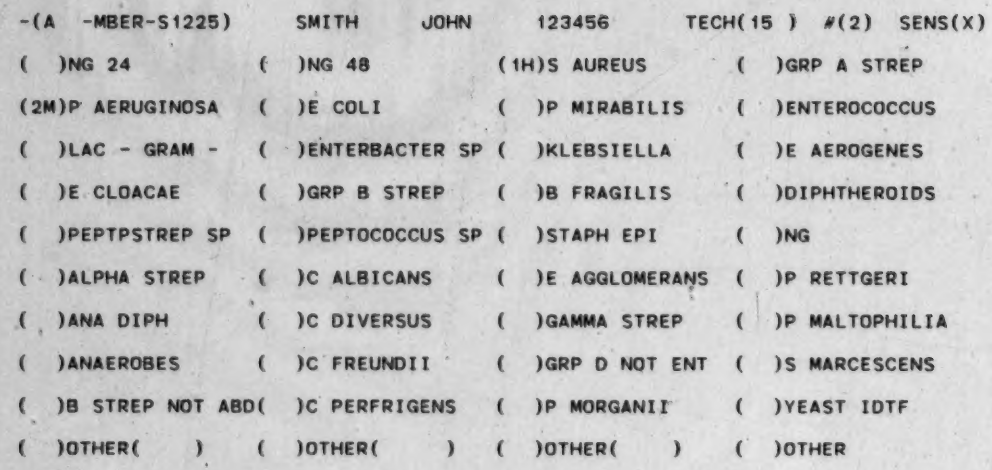
However, the major disadvantage with interactive terminals is that the technologist can become quite terminal-bound. Because each entry has to be displayed for verification, the entry process may become very time-consuming, especially when there are a large number of results to be entered. Also, since some technologists may not be used to manipulating keyboards, the entry process may become a very frustrating one as well. In addition, some have claimed that during heavy usage of the system, the response time is usually prolonged significantly. This is especially true with many of the smaller mini-computer systems. This drawback can be exasperating to the constant users of these terminals.

Specialized Terminals

Other types of data entry devices that have been

```
 (U   -MBGD-S1225 ).  (SMITH          )(JOHN           )( )  G# 123456   LOC(998 )
ROOM( 0751)  BED( 01)   SPECIMEN(EX )   SUB-SPECIMEN(CHEST TUBE     ) LOG( )
COLLECTED: DATE(022475) TIME(1000)  EXAM(BAC ) SMR ONLY( )  DR(00178 )-BARTON
GENITAL: ( )GC          ( )VAGINAL     ( )CERVICAL  ( )LOCHIA    ( )PENILE
         ( )ASPIRATE
SPUTUM:  ( )TRACH ASP   ( )TRAN-TRACH  ( )GASTRIC   ( )NASO-TRACH
         ( )BRONCH      ( )BRONCH-R    ( )BRONCH-L
URINE:   ( )CATHETER    ( )SUPRAPUBIC  ( )CYSTO-R   ( )CYSTO-L   ( )BLADDER
B FLUID: ( )PLEURAL     ( )PERITONEAL  ( )ASCITES   ( )JOINT     ( )DIALYSIS
         ( )B MARROW    ( )CATH TIP
LOGGED: DATE(022475 ) TIME(1145)  X-REF(    )  STAT( )
```

Figure 4. An example of the test request menu used at the Bexar County Hospital District in Chicago is shown here. Data within the brackets are sample entries. Quoted from page 606 of 'Computerization of a hospital clinical microbiology laboratory' by J.H. Jorgensen, et.al. 1978. In Am. J. Clin. Pathol. 69:6 605-614.



```
-(A  -MBER-S1225)     SMITH     JOHN      123456      TECH(15 )  #(2)  SENS(X)
(  )NG 24             (  )NG 48           (1H)S AUREUS       (  )GRP A STREP
(2M)P AERUGINOSA      (  )E COLI          (  )P MIRABILIS    (  )ENTEROCOCCUS
(  )LAC - GRAM -      (  )ENTERBACTER SP  (  )KLEBSIELLA     (  )E AEROGENES
(  )E CLOACAE         (  )GRP B STREP     (  )B FRAGILIS     (  )DIPHTHEROIDS
(  )PEPTPSTREP SP     (  )PEPTOCOCCUS SP  (  )STAPH EPI      (  )NG
(  )ALPHA STREP       (  )C ALBICANS      (  )E AGGLOMERANS  (  )P RETTGERI
(  )ANA DIPH          (  )C DIVERSUS      (  )GAMMA STREP    (  )P MALTOPHILIA
(  )ANAEROBES         (  )C FREUNDII      (  )GRP D NOT ENT  (  )S MARCESCENS
(  )B STREP NOT ABD(  )C PERFRIGENS       (  )P MORGANII     (  )YEAST IDTF
(  )OTHER(     )      (  )OTHER(     )    (  )OTHER(     )   (  )OTHER
```

Figure 5. An example of a result entry menu used at the Bexar County Hospital is shown here. Quoted from page 607 of 'Computerization of a hospital clincal microbiology laboratory' by J.H. Jorgensen, et.al. 1978. Am. J. CLin. Pathol. 69:6 605-614.

described are the specialized on-line microbiology terminals. These are usually interactive keyboards that have been designed especially for a particular microbiology laboratory. Each key on the keyboard has been programmed so that a single keystroke can cause a specific message or result to be generated. Some examples are the bacteriology result entry keyboards marketed by the Digital Numerical Applications (DNA) Co. described by Johnson Associates (1971) and Grams (1979). In this type of system various keyboards are used for the entry of bacteriology culture results, smear results and serology results, etc. All entries can be printed on paper from the built-in printer or via a monitor screen for verification.

These dedicated terminals do have the advantages in that they are easy to use and no coding is required. But they suffer from the problem of lack of versatility and they are often more expensive than a standard terminal.

Mixed Modes

Many on-line laboratory systems use a combination of two or more data entry modes. In fact, most of the recent mark-sense card and document scanner systems that have been described use cards or documents for most result entries, and CRT's for entry of all test requests and results that cannot be processed by the cards or documents.

The Honeywell system described by Lawrie (1979) uses CRT's for all test requesting and optical reader documents for entry of most test results. In addition, any results

that are not on the result documents can be entered via the CRT. Similarly, the Medlab system at the Royal Alexandra Hospital in Edmonton described by Lau (1979) also uses both CRT's and mark-sense cards for test requesting and result entry. In this system, most test requests and result entries are processed via mark-sense cards, whereas those that cannot be processed by cards, for reasons such as specimen type or result phrase not on cards, can be entered via the CRT. In addition, CRT's are used to enter any free-text comment that one may wish to include with certain requests or culture results.

The use of mixed modes allows one to process most of the routine requests and standard test results easily with cards or documents and yet in more complicated requests, where detailed specimen description and reporting of unusual organisms are required, they could be processed via the CRT.

However, because data can be entered interchangibly with CRT's and documents or cards, unless one indicates clearly all the data that have been entered via CRT on the document, one may not be able to tell exactly what data is currently in the computer file. Besides, to acquire both on-line readers and CRT's would mean a much more expensive system than using either one alone at this time.

Bar-code & Wand Readers

Recently, the use of machine-readable bar codes and optical characters for data processing has been suggested by Dudeck (1978) and MacLowry (1978). These machine-readable

codes are usually printed on adhesive labels with printers equipped with optically readable character sets and are used in conjuction with portable optical readers such as wand readers which are used to scan these special ID-labels. An example of this application is in the computer system described by Dudeck (1978) where optical character code labels are used for patient identification. Upon admission, each patient is assigned a ten-digit identification number and a set of labels is then printed which contains the patient identification number, name, sex, ward, etc., and is distributed to the nursing stations where the patient is hospitalized. These labels can be used for patient identification on all kinds of requisitions and specimen containers. When the specimen is received in the laboratory, one can retrieve all the relevant information on the terminal for verification simply by scanning the ID-label with a wand reader.

The main advantage of these devices is that they provide a highly accurate and rapid means of patient identification in a computerized system. Instead of keypunching in the patient identification or accession number, one merely has to scan the label with a wand reader to retrieve the appropriate patient record from the computer file with virtually no chance of error, thus enabling one to review the type of request desired with the patient data.

At the present moment, this technology is limited only to positive patient identification. The use of these devices

for data acquisition has also been suggested, but it would require much improvement and refinement in order to become acceptable to most clinical laboratories.

Automatic Reporting of Negative Results

Another useful feature of the computer is its ability to automatically generate negative culture reports. An example of this feature is in the microbiology system at the Massachusetts General Hospital described by Kunz (1976): As soon as a blood or urine culture is requested and logged into the system, the computer will automatically update the result status to 'NEGATIVE'. Unless a positive result is entered on the following day, the result will be generated that following evening as 'NEGATIVE TO DATE'. Since about one-quarter of the typical workload in a microbiology laboratory consists of these urine and blood cultures, and since the majority of these cultures are usually negative, this would mean a tremendous saving in the technologists' time that would otherwise have to be spent writing up these negative reports.

It should also be possible to extend this useful automatic reporting feature to include other negative cultures as well. But one would have to be very careful in the design of the reporting logic involved so there would not be any chances of omission of positive culture results. Despite the vast potential of this reporting feature, it hasn't been widely accepted, and there has been sparse documentation in this regard.

D. USE OF WORKSHEETS

Despite the fact that many data entry modes are available for entering microbiology results, there is one aspect that is common to most computerized microbiology systems, that is, all of the initial observations, including the colonial morphology, and all the biochemical tests, culture transfers, etc., are recorded onto some form of worksheet prior to entering the relevant results into the computer system. These worksheets can vary from being a blank sheet of paper to computer-printed workcards or optical reader documents. For example, with the Medlab system used at the Royal Alexandra Hospital (Lau 1979), the back of the test request card is conveniently used for recording all results. An adhesive ID-label that contains the patient name, ID, accesion number, test name, specimen type, etc., is affixed onto the card for identification. Organism results are then transcribed onto the culture result mark-sense cards.

As for on-line terminal systems, the Foothills Hospital in Calgary uses a number of pre-printed worksheets that contain sufficient blank area on the front for recording all the results. In addition, the most common tests to be performed are included on the worksheet and are checked-off during the identification stage and are tallied and entered via the DecWriter at the end. The back of the worksheet contains a listing of the most commonly encountered specimen

types and organisms and their numeric codes. A label containing an accession number is affixed onto the worksheet for identification. An example of one of these worksheets is shown in plate 3.

At the Massachusetts General Hospital in Boston (Kunz 1976), computer-printed workcards are used to record all test results. Each workcard is identified by computer-printed patient ID, name, accession number, specimen type and the test requested, etc. Samples of these workcards are shown in plate 4. Similarly, the optical reader documents used in many of the systems are computer-printed and each document contains a unique serial number for identification. In addition, these documents usually contain a work area for recording all observations and test results. This area is not read by the document scanner. See plate 2 for an example of an optical reader document with both the reporting and work areas on the same sheet.

Finally, a one-step process has also been described by Williams (1978) for his system at the St. Thomas Hospital in England. In this system a computer-printed optical reader document, 14x11 inches in size, is used which allows all results, including colonial morphology, biochemical tests, etc., to be recorded in machine-readable form, in addition to the smear, organism, and sensitivity results that are usually reported. All the results are processed through the scanner and stored in the computer file. However, only

Plate 3 a, b. An example of a microbiology result worksheet used at the Foothills Hospital in Calgary.a - front side, b - back side

FOOTHILLS HOSPITAL

GENERAL

Sputum	06 Ears	09 Vaginal	04	1. Bact #
Auger	05 Eyes	14 Mi. vag.	04	
Trac. asp.	05 CSF	12 Cervix	04	6. DATE
Bronchial	05 FI	13 Urethral	04	day-month-year

1 ☐☐☐☐☐☐ 5

6 ☐☐☐☐☐☐ 11

12. Specimen 12 ☐☐ 13

14 STATUS 14 ☐
IP - 0
OP - 1
HS - 2
Ref. - 3

15 AGE 15 ☐
NB - 0
0/1 - 1
2/15 - 2
16/50 - 3
> 50 - 4

16 Organism 1 16 ☐☐☐ 17
18 Organism 2 18 ☐☐☐ 19
20 Organism 3 20 ☐☐☐ 21

Sensitive - 0
Resistant - 1

	P	E	Te	Cx	Am	CC
BLOOD I	+ C					
	- C					
	+ B					
	- B					
	Yeast					
	NG					
Sch An	+ C					
	- C					
Ph An	+ B					
	- B					
	NG					
MAC	LF					
	NLF					
	NG					
PHENYL	+ C					
	+ B					
	NG					
GC	+					
	-					
	NG					
CHOC.	+ C					
	- C					
	+ B					
	- B					
	NG					
THIO						
	BL SS					
	Choc. P					
BHI	TP					
	BI An					
	Ph An					
	NG					

WM				
GT				
XV				
Coag.				
OF				
BEA				
Lanc.				
Bile				
Sens.				
MMS				
API				
OF				
Sens.				
MMS				
API				
OF				
Sens.				
CTA				
FA				
Choc				
Sens				
WM				
GT				
Coag.				
OF				
BEA				
Lanc.				
Bile				
XV				
LF				
NLF				
Sens.				

DIRECT	+ C	Staph	WBC	Mucous
	- C	Diplo	Assoc.	Debris
	+ B	Strep	Sg. ep.	
	- B	Enter	RBC	
	Mixed	Hemoph	Trich	
	Neg.	Micro	NOS	

	# 1	# 2	# 3
Clindamycin	31	56	69
Erythromycin	28	47	64
Methicillin	20	45	64
Penicillin	21	54	73
Ampicillin	22	61	68
Cephalosporin	26	43	62
Gentamicin	29	48	67
Tetracycline	27	50	75
Carbenicillin	23	47	61
Chloroamphen	25	66	63
Kanamycin	30	49	68
Tobramycin	40	59	78
Nitrofuran	34	53	72
T/S	29	58	77
Polymixins	36	55	74

DATA PROCESSING

L-52 (Rev.77)

3 a. Front side.

SPECIMEN CODE Line 12

Abscess	00	Urogen	04	Nose	08	CSF	12
Wound	01	Auger	05	Ears	09	Other fluids	13
Drainage	02	Sputum	06	Urine	10	Eyes	14
Stool	03	Throat	07	Blood	11	Misc.	15

ORGANISM CODE Lines 16 - 21

Aeromonas	00	Ent. hafnia	13	Pr. mirabili	23	Strep. B	35
Alk. dispar.	01	H. influenzae	14	Pr. morgani	24	Strep. C	36
Arizona	02	Hemoph. oth.	43	Pr. rettgeri	25	Strep. D	37
Bacteroides	03	Herella	49	Pr. vulgaris	26	Strep. G	38
Citrobacter	04	K. pneumonia	15	Providence	27	Strep. AN	39
Cl. welchii	05	K. oxytoca	16	Ps. aerogin	28	Strep. oth.	46
Cl. others	06	Kleb. others	44	Ps. others	29	Strep. pneu.	40
E. coli type	07	Listeria	17	Sal. typhimu	30	C. albicans	41
E. coli oth.	08	Mima	18	Sal. others	45	C. others	42
Esch. sp.	09	Morazella	19	Serratia	31	Myco. tuber	47
Ent. aerogen	10	N. gonococci	20	Shigella	32	Myco. other	48
Ent. cloacae	11	N. meningo	21	Staph. aurea	33	Staph. albus	50
Ent. liquef.	12	Pasteurella	22	Strep. A	34	E. agglomerans	51
						Yersinia sp.	52
						Erwinia	53
						Eubacterium	54
						Veillonella	55
						Peptococcus	56
						Propionibacterium	57
						Micrococcus	58
						Flavobacterium	59
						Misc.	60

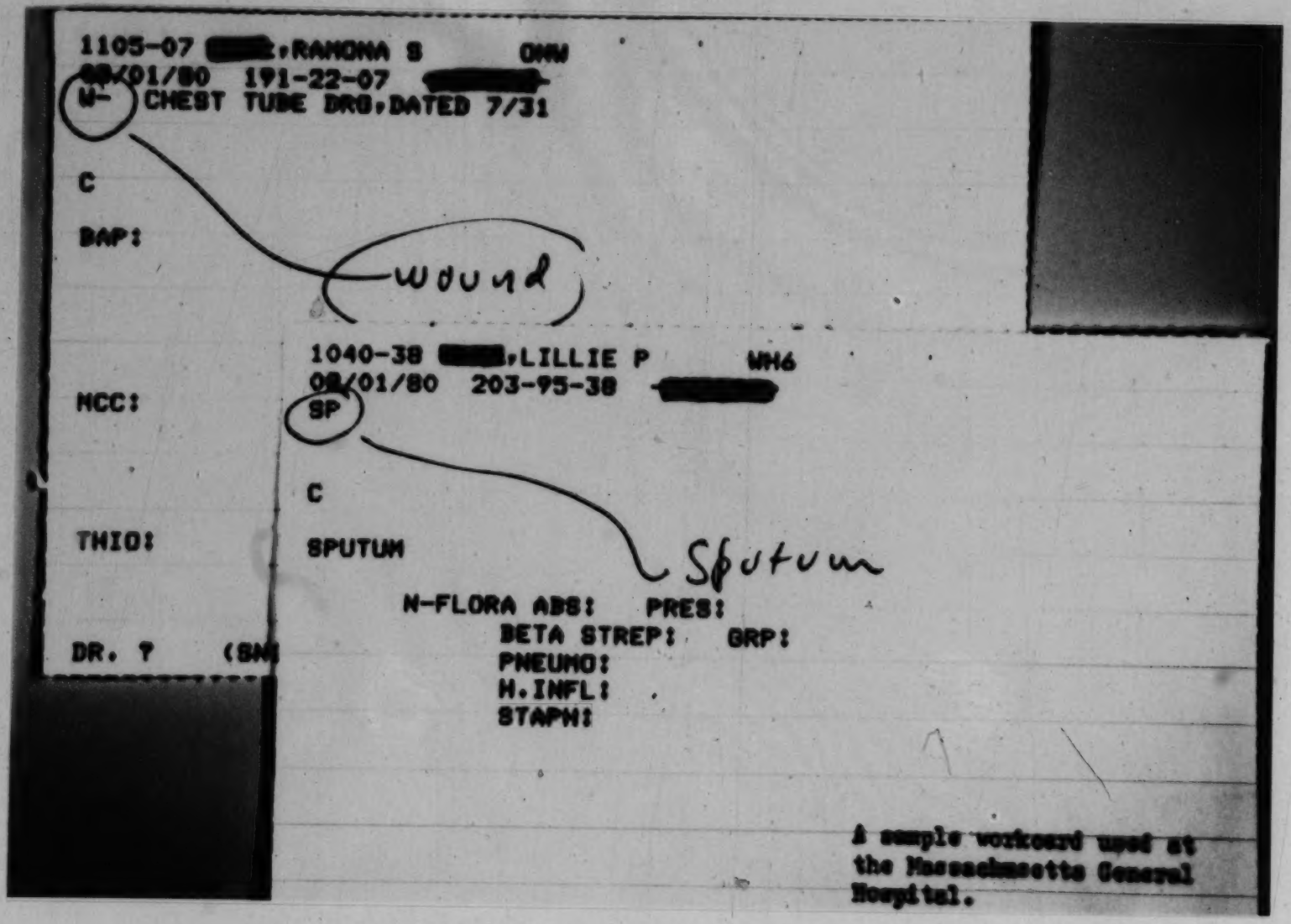
NOTE: Some of the worksheets are set up with media to include anaerobic and special procedures. You don't have to use them all. Please cross out any that are not used.

General guide, when one plants anaerobic cultures:

1. On certain abscess wounds and drainage as indicated by clinical data on request form.
2. On bronchial washes, tracheal aspirations, pleural fluids and miscellaneous fluids as

3 b. Back side.

Plate 4. An example of the microbiology result workcards used at the Massachusetts General Hospital in Boston.



A sample workcard used at the Massachusetts General Hospital.

relevant results, such as gram smear, organism, and sensitivity results would appear in the reports. An example of this worksheet is shown in plate 5.

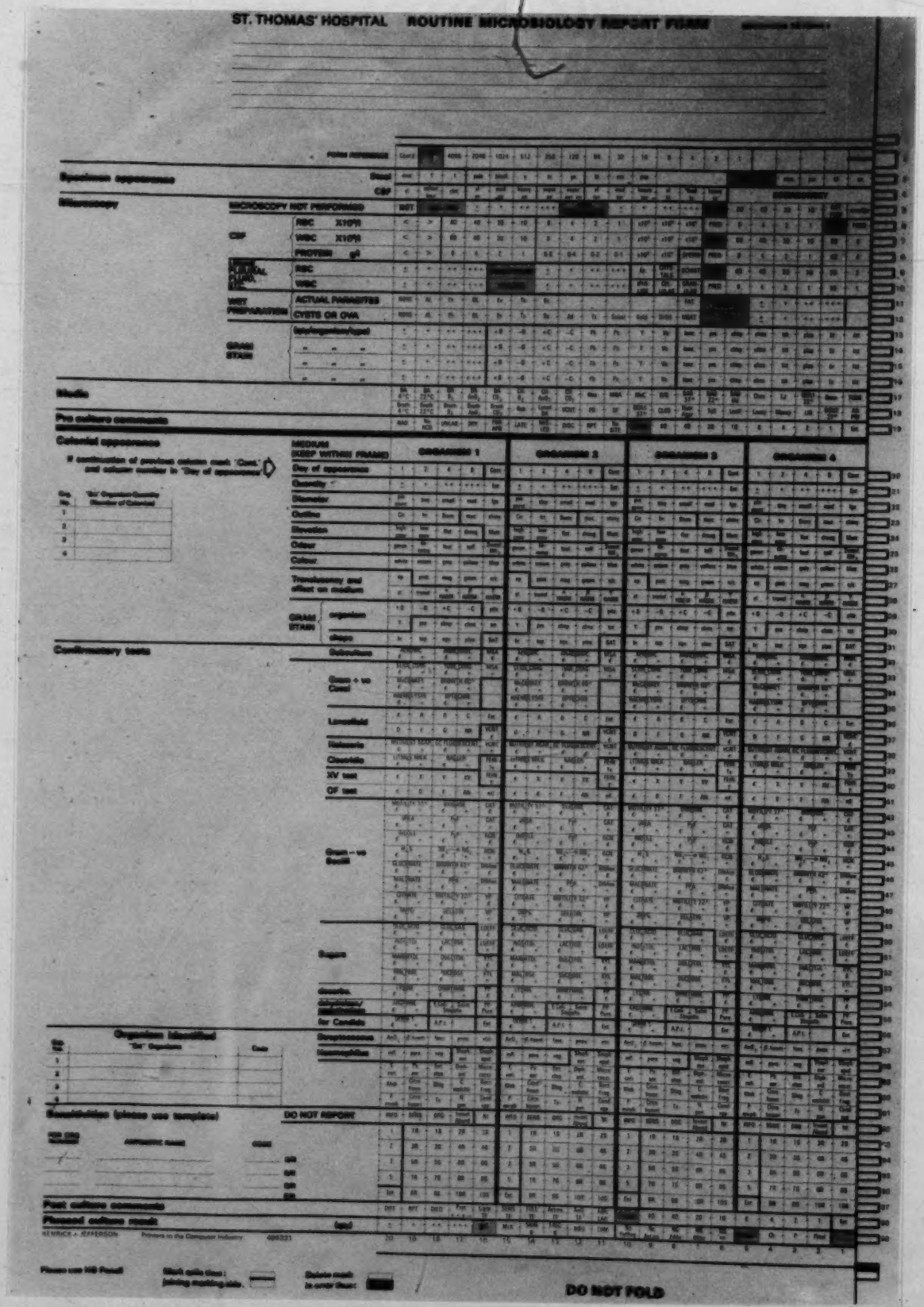
This particular method has been claimed to be advantageous because one may enforce quality control on the work by checking the validity of each test and result against various predefined standards in order to detect any discrepancies and errors. However, the document would tend to impose restrictions on the procedures within the laboratory, and it would require careful and complicated programming involving the reporting logic.

E. ERROR CHECKING & RESULT VERIFICATION

One of the responsibilities associated with the microbiology laboratory is the assurance in the quality and correctness of its work and the patient reports it produces. These range from ensuring the accuracy and likelihood of the test results, reporting of all required result data, and consistency in the correct spelling throughout the entire report. In the past, it has been the responsibility of the senior technologists to verify each report before it is released. However, despite the exertion of a high degree of technical expertise and competence, error checking and result verification are monotonous, demanding and error-prone procedures when large numbers of specimens are reported on.

With the introduction of the computer, it seemed

Plate 5. An example of the microbiology result entry optical reader document used at the St. Thomas Hospital in England.



ST. THOMAS' HOSPITAL ROUTINE MICROBIOLOGY REPORT FORM

DO NOT FOLD

conceivable that the computer, because of its ability to make logical decisions based upon a set of predefined parameters, may indeed be able to lighten the burden by performing the functions of error-checking and result verification automatically. But as Kunz (1976) has pointed out, the establishment of these limits is far-more complex than deriving the normal ranges for other laboratory disciplines, such as chemistry, and would require more logical deductions and imagination. Both Harvey (1972) and Goodwin (1976) have described the use of some error-checking routines which include checking of invalid specimen and result codes, reporting of conflicting or unnecessary antibiotic results, and generation of appropriate comments in the patient reports where warranted. In the system described by Williams (1978), all biochemical tests that are entered are also checked against a set of organisms with predefined reactions for improbable biochemical results for the organism reported. Certain reports, such as growth from sites that are usually sterile etc., are also held back automatically for scrutiny by the microbiologist. Kunz (1976) has also described the extensive checking of antibiotic test results obtained with Kirby-Bauer technique for any discrepancies between the antibiotic susceptibility patterns and organism identifications. In addition, computer-generated suggestions on steps to be taken to resolve the problems when such a discrepancy does occur are printed along with the original test results. This is not

only an ideal form of automated quality control procedure but also an effective device for teaching technologists meaningful laboratory procedures. An example of such a computer-generated discrepancy report is given in figure 6.

F. PATIENT REPORTS

General Remarks

One of the most important functions of the microbiology information system is to distribute all available results to the doctors promptly. This is most commonly achieved through the generation of various types of computer-reports in batches at the data centre areas which are then distributed to the nursing stations or directly to the doctors.

Another alternative is to install remote on-line terminals or printers on the nursing stations that would allow direct retrieval of any available results. In the past, this has been considered to be generally unfeasible because of the cost involved. At present, however, with the cost of computer equipment significantly reduced, some laboratories have begun to install terminals directly on nursing stations such as Intensive Care Units (ICU), Coronary Care Units (CCU), etc., where instant retrieval of results would be most useful. So far, the outcome of this attempt has proven to be quite successful.

Regardless of the means of access, these culture results would have to be arranged in some way that would be readily visible and informative to the doctors. In most

400-30-23 PATIENT NAME-ID 7456-24 MISC- (ENTEROCOCCI--METH)

PROBLEM: METHICILLIN SENSITIVE ENTEROCOCCI

1. REPEAT SENSI STILL 14 OR MORE? YES...NO...

   ZONE SIZE...

   ARGININE POS....NEG....

   SUCROSE AGAR (GUMDROP COLONIES) POS....NEG....

   STARCH HYDROLYSIS POS....NEG....

3. IS ORGANISM S. BOVIS YES....NO....

4. IF NOT BOVIS REFER FOR GROUPING GROUP....

Figure 6. Example of a computer-generated report of one type of apparent discrepancy between antibiotic susceptibility and identification of an organism. Quoted from page 192 of 'Role of the computer in microbiology' by L. Kunz et.al. in 'Modern methods in medical microbiology - systems and trends' edited by J.E. Prier, J. Bartola, H. Friedman. 1976. University Park Press.

cases, the date/time of request, specimen type, test name, patient ID and name, and the accession number, etc., are included for proper identification. If results are printed in batches as reports, they may be grouped chronologically according to the dates of requests, or by the specimen types. One may further integrate microbiology results with other test results, such as those from hematology or clinical chemistry. Such standardized report formats should make result interpretation easier for the doctors.

Types of Reports

Generally patient reports may be classified into three types - the *cumulative* , the *summary*, and the *daily* report (Toren 1978). The characteristics of these reports are described briefly as follows:

Cumulative Report

A cumulative report contains an accumulation of all the laboratory work done on a patient since the beginning of his hospitalization. This report is useful in cases where doctors may wish to monitor the patient's trend and progress since the beginning of hospitalization. However, in most cases, this report has not been found to be too useful, because for patients with a short hospital stay or little laboratory work done, the report is only marginally more convenient than separate culture reports. On the other hand, for patients with numerous test results or long term stay, the report may grow to an unmanagable size and require

much time to print. As a result, most laboratories tend to use either summary reports and/or daily reports instead.

Summary Report

A summary report is also cumulative in nature, but only results within a specified time period are printed. Usually this would be the most recent seven day period since hospitalization.

With some systems, such as the Medlab system, summary reports are printed daily on all patients. Whereas others, such as the one described by Kunz (1976), they are printed only if there is new result information that warrants an updated report. In both cases, the nursing staff are required to discard any previous copies upon the receipt of the new report, and also to keep the 7th day report as the permanent copy. With this summary report, the doctor can obtain the most recent information on his patient without having to search through all the laboratory results as in the case of a cumulative report. However, the fact that the summaries are printed regularly causes problems because there are usually some staff who are reluctant to discard any reports, and so the station soon ends up with many versions of these reports, which can lead to confusion. Besides, the routine printing of these reports is a costly operation both for report forms and computer time.

Daily Report

A daily report usually consists of only the request that contains new result information. It is usually printed during the day and is used mainly to inform the doctors of the progress of a particular culture. The contents of these reports are usually brief and compact because they are for quick references only, and are to be replaced by more comprehensive reports at later time during the day, such as the summary report.

Report Format

A crucial factor that frequently determines the success or failure of a computerized microbiology information system is in the appearance of its patient reports. It is obvious that, if the computer system is to gain wide acceptance from the medical staff, the format of its patient reports must be neat, informative, and easy to interpret.

Basically, patient results can appear either vertically or in a combined vertical-horizontal form on a report. The horizontal format used in chemistry, where test results are printed in chronological order across the page, is not usually applicable to microbiology due to the presence of narrative results which tend to exceed the page width.

Patient results are usually sorted chronologically according to the date of requests, and some may be further sorted by the test procedures and/or specimen types. In the vertical format, results are printed down the page in a sequential fashion. If one page is exceeded, the results

would extend to the next consecutive page. Reports in this format are not spatially restricted and can contain more detailed descriptions. But if a large number of results are present, it is often necessary to search through a number of pages in order to find the desired result. Secondly, there is also the problem of excess paper, which is frequent when reports are printed in this format. An example of this type of report described by Vermeulen (1972) is shown in figure 7. An improved and more compact form of this type of report described by Kunz (1976) is shown in figure 8.

The combined vertical-horizontal format is unique in that usually either the antibiotic or organism names are printed horizontally across the page in the report. This format is often intended for maximal use of space and results in this form are usually abbreviated to some extent and tend to be more compact. Examples of this type of report described by Grams (1979) and Lupovitch (1979) are shown in figures 9 and 10, respectively.

Distribution of Reports

Once the patient reports are generated, they are delivered to the nursing stations by some means. This is most commonly achieved either by messenger delivery service or by having nursing staff come to pick up reports in the laboratory. With these methods, the problems associated with manual delivery of reports, such as misplacement and delay in delivery, remain unresolved. In hospitals where some form of rapid mechanical delivery system is available, such as

Figure 7. An example of a patient report with a vertical format used at the Baltimore Cancer Research Centre, Baltimore, is shown here. Quoted from page 416 of 'A computerized system for clinical microbiology' by G.D. Vermeulen et.al. 1972. Am. J. Clin. Pathol. 57 : 413-418.

BALTIMORE CANCER RESEARCH CENTER
US PHS HOSPITAL BALTIMORE, MD 21211

MICROBIOLOGY FINAL REPORT

123456
SMITH, JOHN
THIS IS AN EXAMPLE OF FREE TEXT
SPECIMEN TAKEN 8/12/68
SPECIMEN SENT 8/12/68
SOURCE - THROAT
CULTURE NO. 1608
TYPE OF ANALYSIS - ROUTINE CULTURE
ANALYSIS PERFORMED BY MICROBIOLOGY RESEARCH LABORATORY
BALTIMORE CNCER RESEARCH CENTRE, BALTIMORE, MD.

RESULTS --

GENUS - STAPHYLOCOCCUS
SPECIES - EPIDERMIDIS
GROWTH QUANTITATION -- 1+

GENUS - STAPHYLOCOCCUS
SPECIES - AUREUS
GROWTH QUANTITATION -- 2+
FOLLOWING LINE IS A LABORATORY COMMENT
THIS IS A SECOND EXAMPLE OF FREE TEXT
SENSITIVITIES --

PENICILLIN	RESISTANT
ERYTHROMYCIN.....	SENSITIVE
OXACILLIN.....	SENSITIVE
METHICILLIN.....	SENSITIVE
CLOXACILLIN.....	SENSITIVE
LINCOMYCIN.....	SENSITIVE
AMPICILLIN.....	RESISTANT
CEPHALOTHIN.....	MODERATELY SENSITIVE
STREPTOMYCIN.....	RESISTANT
TETRACYCLINE.....	RESISTANT
CHLORAMPHENICOL....	SENSITIVE
KANAMYCIN.....	SENSITIVE
NEOMYCIN.....	SENSITIVE

GENUS - DIPHTHEROIDS
SPECIES - (NO ENTRY TRANSMITTED)
GROWTH QUANTITATION -- 1+

GENUS - NEISSERIA
SPECIES - (NO ENTRY TRANSMITTED)
GROWTH QUANTITATION -- 1+

BY _____

Figure 8. An example of a patient report with a vertical format used at the Massachusetts General Hospital is shown here. Quoted from page 187 of 'Role of computer in microbiology' by L. Kunz in 'Modern methods in medical microbiology - systems and trends' edited by J.E. Prier, J. Bartola, H. Friedman. 1976. Univeristy Park Press.

09/04/74 MGH FRIEDMAN F. BF3 105-34-46

--- URINE

08/30 URINE SN:7345
FINAL REPORT: NO GROWTH

08/30 URINE SN:7560
FINAL REPORT: NO GROWTH

--- SPUTUM

08/30 SPUTUM SN:7171
FINAL REPORT:
SMEAR..MODERATE GRAM POSITIVE COCCI IN CLUSTERS - FEW GRAM
..POSITIVE RODS FEW POLYS ABUNDANT CELL FRAGMENTS
CULTURE:
ABUNDANT STAPH AUREUS
PEN R METH S ERYTH S CEPH S TETRA R
CHLOR S
SCANT NORMAL FLORA PRESENT

08/31 SPUTUM SN:7587
ABUNDANT STAPH AUREUS
? ABUNDANT PNEUMOCOCCI
NORMAL FLORA PRESENT

08/31 SPUTUM SN:7623
FINAL REPORT:
ABUNDANT STAPH AUREUS
SEE EARLIER CULTURE FOR SENSITIVITIES
ABUNDANT PNEUMOCOCCI

09/03 SPUTUM SN:8478
ABUNDANT GRAM NEG ROD #1
ABUNDANT ENTERIC GRAM NEG ROD #2

09/04 SPUTUM SN:8976
SMEAR..ABUNDANT GRAM POSITIVE AND GRAM NEGATIVE ORGANISMS
..MIXED MORPHOLOGY WITH GRAM POSITIVE COCCI IN PAIRS
..PREDOMINATING ABUNDANT POLYS AND CELL FRAGMENTS
CULTURE: PEND

--- BLOOD

08/30 BLOOD- SN:7327 NEG TO DATE

08/30 BLOOD- SN:7324 NEG TO DATE

SHANDS TEACHING HOSPITAL/CLINICS LABORATORY CHART REPORT

WARD: SURGICAL DAILY CHART REPORT PAGE 3

NAME: SMITH, CATHERINE A MEDICAL RECORD 4302930

ROOM: H641C B2Y F OO DR: MacKINTIRE 16:14 07/18/76

PROBLEM: NONE GIVEN

MICROBIOLOGY

BLOOD CULTURE	BLOOD CULTURE
7/07/76 16:15	NO GROWTH TEST COMPLETE
BLOOD CULTURE	BLOOD CULTURE
7/07/76 09:45	NO GROWTH TEST COMPLETE
MISC ROUTINE CUL 07/12/76 09:45	WOUND PSEUDO AERUGIN LIGHT (1+) ENTEROCOCCI FEW (+/-) BACTEROIDES FRAG MODERATE (2+) PROTEUS MIRABILI IN SUBCULTURE TEST COMPLETE

	PSEUDO AERUGI	ENTEROCCI	BACTEROIDES F	PROTEUS MIRAB
TOBRAMYCIN	S	R		S
DOXYCYCLINE			R	
CEPHALOTHIN	R	R	R	S
GENTA	S	R		S
AMPICILLIN	R	S	R	S
KANAMYCIN	R	R		S
CARBENICILLIN	S	R		S
CHLORAMPHENICOL	R	S	S	S
ERYTH			S	
PENICILLIN			R	
TETRACYCLINE	R	R	R	R

END OF REPORT

Figure 9. An example of a microbiology patient report with a combined vertical-horizontal format used at the Shands Teaching Hospital is shown here. Quoted from page 161 of 'Medical information systems' by R. Grams 1979. Published by Humana Press Inc.

HOLY CROSS HOSPITAL
DEPARTMENT OF PATHOLOGY

	CLINDH	ERYTHO	LINCOO	VANCOO	AMPP	CEPHOA	CHLORA	GENTOA	KANAA	PENN	TETRA	CARBR	SXT	SULFA	POLYMA	STREPA	TOBRA
12/16/77 07:50 URINE	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
73510 (3RD REPORT)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SMEAR:	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
FEW GP COCCI	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
NUMEROUS GN BACILLUS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
CULTURE:	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
QUANTITY >100,000/ML	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
FEW STREP FECALIS	R	S	R	R	S	S	I	R	S	S	R	R	.	.	.	.	.
NUMEROUS E COLI	.	.	.	.	.	R	S	S	S	R	R	S	R	S	S	S	S
BIOTYPE 594743	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
12/10/77 09:35 SPUTUM	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
73740: (2ND REPORT)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SMEAR:	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
FEW GP DIPLOCOCCI	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
FEW PMNS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
CULTURE:	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
NUMEROUS STREP PNEUM	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
MODERATE E COLI	.	.	.	.	.	R	S	S	S	S	R	S	R	S	S	S	S
BIOTYPE 65044502	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

****
* MICROBIOLOGY *
* CUMULATIVE REPORT *
* 12-20-77 -- 09:05 *
****

8765843-4
DANIELS, JOHN 54M
2545-2 DR A PERRY

PAGE 1

Figure 10. An example of a microbiology patient report with a combined vertical-horizontal format used at the Holy Cross Hospital is shown here. Quoted from page 842 of 'Manual & computerized cumulative reporting systems for the clinical for the clinical microbiology laboratory' by A. Lupovitch et. al. 1979. Am. J. Clin. Pathol. 72 : 841-847.

the pneumatic tube system, the problem of report distribution is not as significant. Yet reports would still have to be separated manually according to stations prior to their distribution.

There have been various attempts to eliminate the problems regarding the distribution of patient reports. Most commonly these involve installing on-line terminals or printers on nursing stations which allow results to be transmitted directly. But at present, this practice has not been widely accepted due to its high initial cost.

G. STATISTICAL REPORTS

Most of the microbiology information systems described are able to generate some types of statistical reports. However, the implementation of these additional features usually depends on the total system load, and in many of the smaller or mini-computer systems, only a limited number of these additional features can be implemented because the systems are already at full capacity in handling the major tasks such as patient admission, test requesting, result entry, and patient report generation.

Still, one of the most important secondary gains in the application of computer technology to the microbiology laboratory is the concomitant acquisition of a computer-based clinical information system that provides various statistical analyses and evaluations with minimal manual effort. Secondary benefits, such as the accumulation

of workload statistics, and specimen tallies, etc., are already providing much more accurate information on the number of test procedures performed and specimens processed by the particular laboratory. The infection control reports that are available in some of the systems are also providing valuable information that was not previously obtainable.

A review of some of the more common statistical reports that have been described is given in the following sections.

Laboratory Statistics

The most common types of computer-generated laboratory statistical reports are probably the *workload statistics report*, the *overdue culture summary*, and the *significant result summary*. The data in these reports are usually tallied automatically by the computer at the time when the specimens were processed and they usually do not require any additional manual input. An example of the workload statistics report available in the Meditech microbiology system is shown in figure 11. The overdue culture summaries are especially useful in most microbiology laboratories because they contain the patient data whose cultures have not had results reported within a specified time period, so the laboratory staff can trace missing specimens and cultures that need reporting. This was usually not feasible previously due to the large number of cultures involved. An example of such an overdue culture summary offered in the Meditech system is shown in figure 12.

The computer can also be programmed to print out the

RUN: NOV 1, 1978
11:00 AM

MEDITECH DEMO HOSPITAL
WORKLOAD STATISTICS
BACTERIOLOGY

BY DEPARTMENT

PROCEDURE #	MTD ALL	INP STAT	MTD ALL	OUT STAT	MTD TOTAL	YTD TOTAL	WORK UNITS	GROSS WU	MTD BILL	FEE	REVENUE
100.000 GRAM SMEAR	220	8	166	10	387	4628	2.2	854.1	387	2.00	774.00
105.000 AFB SMEAR	69	4	47	2	116	1369	12.0	1392.0	116	4.00	464.00
110.000 FUNGUS SMEAR	82	6	28	1	110	1321	7.0	770.0	110	3.00	330.00
120.000 COLONY COUNT	201	0	160	0	361	4347	21.5	7761.5	361	7.00	2527.00
121.000 SEDIMENT CULTURE	31	0	65	0	96	1144	18.5	1835.5	339	8.00	2527.00
125.000 URINE CULTURE	323	0	16	0	339	4075	21.5	473.0	192	7.00	1344.00
135.000 THROAT CULTURE	32	0	160	0	192	2300	21.5	8730.0	465	5.00	2320.00
145.000 BLOOD CULTURE	445	0	45	0	465	5577	18.0	8370.0	465	5.00	665.00
160.000 GENITAL CULTURE	25	0	21	0	31	372	20.5	20.5	635	7.00	217.00
220.000 FUNGAL CULTURE	23	0	21	0	44	527	30.5	1320.0	44	8.00	184.00
240.000 TB CULTURE	5	0	16	0	21	38	9.5	361.0	38	6.00	228.00
TOTAL	1320	18	524	13	1379	24689	36704.9	3029	3029		15487.00

Figure 11. An example of a typical workload statistics report offered in the Meditech system is shown here. Explanatory notes: MTD - month-to-date, INP STAT - inpatient statistics, OUT STAT - outpatient statistics, YTD - year-to-date. Quoted from the Meditech 'Microbiology system - report examples' by Medical Information Technology Inc. 1978.

RUN: JAN 31, 1978
7:45 AM

MEDITECH DEMO HOSPITAL
CUMULATIVE OUTSTANDING PROCEDURES

BY PROCEDURE

PROCEDURE	SPEC #	STATUS	LOG DATE	COL DATE	NAME	ID #	STATUS
GRAM STAIN	0130:9048R	RECEIVED	1/30/78	1/30/78	HALLOGAN, KATHERINE	1000054	OUT
		ORDERED: R/O BETA STREP CULTURE					
	0130:9049R	RECEIVED	1/30/78	1/30/78	MCGUIRE, JAMES M	1000788	OUT
		ORDERED: SPUTUM CULTURE					
	0130:9054R	RECEIVED	1/30/78	1/30/78	PETRELLI NICOLA	1000088	OUT
		ORDERED: GENITAL CULTURE					
	0143:9070R	RECEIVED	1/30/78	1/30/78	URQUHART, PETER	1009865	OUT
		ORDERED: URINE CULTURE W COL CNT					
	0143:9043R	RECEIVED	1/30/78	1/30/78	SCHAFFER, FLORENCE	1000670	OUT
		ORDERED: MISCELLANEOUS CULTURE					
AFR CULTURE	0130:0944R	RESULTED	1/30/78	1/30/78	WEENE, JOSEPH	1000596	INP
		ORDERED: SPUTUM CULTURE, TB CULTURE					
	0130:9071R	RECEIVED	1/30/78	1/30/78	SMITH, FRANK C	1000023	INP
		ORDERED: FUNGUS CULTURE, TB CULTURE, MISCELLANEOUS CULTURE					
URINE CULTURE	0127:9007R	RECEIVED	1/30/78	1/30/78	MOUTIFIS, ALEXANDER	1000321	OUT
		ORDERED: URINE CULTURE W COL CNT					
	0129:9012R	RESULTED	1/29/78	1/29/78	BAILLY, JEAN W	1000003	INP
		ORDERED: URINE CULTURE W COL CNT					

Figure 12. An example of a typical overdue culture summary offered in the Meditech Microbiology system is shown here. Quoted from 'Meditech Microbiology system - report samples' By Medical Information Technology. 1978.

patients whose cultures have grown pathogens considered to be significant. For example, any growth in bloods and CSFs or of organisms such as *Pseudomonas aeruginosa*, *Salmonella*, *Shigella*, etc., would be considered significant and they may require follow-up by the infectious disease service. Therefore it is desirable that these patients be listed in order for the laboratory to take the appropriate action. An example of such a report described by Kunz (1976) is shown in figure 13.

Antibiotic Susceptibility Profile Reports

In most systems, the antibiotic susceptibility data that have been accumulated in the patient records are usually tallied at designated periods to derive the susceptibility percentages of certain organisms to various antibiotics. These statistics can then be used to assist the physicians in selecting the antibiotic that would be most appropriate in treating the infection. These percentages can be further broken down according to specimen sources so one could compare the susceptibility patterns of organisms isolated from various sites. Examples of these reports produced by the Microbiology Department of the University of Alberta Hospital are shown in figures 14, 15, respectively.

Kunz (1976) has also described the use of computer-generated histograms that plot the susceptibility of a particular organism to an antibiotic and also the comparison of antibiotic susceptibilities of a particular organism to two or more antibiotics. The analysis of these

STAPH AUREUS
(001 THIS MONTH, 016 THIS QUARTER, 036 LAST QUARTER)

JOHN DOE	103-29-40	BM5	3584	09/23/74

STAPH EPIDERMIDIS
(002 THIS MONTH, 041 THIS QUARTER, 093 LAST QUARTER)

DICKENS JOAN	104-39-80	OREC	4016	09/23/74
POPPINS MARY	908-55-75	WB12	6832	09/29/74

STREPTOCOCCI PROBABLY ENTEROCOCCI
(001 THIS MONTH, 010 THIS QUARTER, 014 LAST QUARTER)

THELROUDY ALFRED	055-48-20	PH6	7366	09/30/74

Figure 13. Portion of report of positive blood cultures for epidemiological analysis used at the Massachusetts General Hospital. Quoted from page 190 of 'Role of computer in microbiology' by L. Kunz in 'Modern methods in medical microbiology - systems and trends' edited by J.E. Prier, J. Bartola, H. Friedman. 1976.University Park Press.

228/00000 AS OF 11SEP79

TO 1000

UNIVERSITY OF ALBERTA HOSPITAL

000,790911-2123

REPORT 8312 ANTIBIOTIC SENSITIVITIES / ORGANISM IN %

STAPHYLOCOCCUS AUREUS 01MAR79 - 31AUG79

	NR	SEN	MOD	RES
PENICILLIN	47	31.91	.00	68.09
OXACILLIN	47	100.00	.00	.00
ERYTHROMYCIN	47	89.36	.00	10.64
CLINDAMYCIN	1	100.00	.00	.00
CEPHALOTHIN	47	100.00	.00	.00
KANAMYCIN	47	91.49	.00	8.51
GENTAMICIN	47	93.62	.00	6.38
CO-TRIMOXAZOLE	1	100.00	.00	.00
VANCOMYCIN	1	100.00	.00	.00
CEFOXITIN	12	100.00	.00	.00
RIFAMPIN	1	100.00	.00	.00
CEFAMANDOLE	12	100.00	.00	.00
CEPHRADINE	12	83.33	16.67	.00

STAPHYLOCOCCUS EPIDERMIDIS

	NR	SEN	MOD	RES
PENICILLIN	49	2.04	.00	97.96
OXACILLIN	49	100.00	.00	.00
ERYTHROMYCIN	49	95.92	2.04	2.04
CLINDAMYCIN	1	100.00	.00	.00
CEPHALOTHIN	49	100.00	.00	.00
KANAMYCIN	49	89.80	.00	10.20
GENTAMICIN	48	89.58	.00	10.42
CEFOXITIN	13	100.00	.00	.00
CEFAMANDOLE	13	100.00	.00	.00
CEPHRADINE	13	84.62	15.38	.00

Figure 14. An example of the Antibiotic Susceptibility Profile Report, giving the overall percentages of susceptibility of each major type of organism to various antibiotics, used at the University of Alberta hospital, is shown here.

228/00000 AS OF 11SEP79 UNIVERSITY OF ALBERTA HOSPITAL 0000,790911-2123

REPORT 8312 ANTIBIOTIC SENSITIVITIES / ORGANISM IN %

STAPHYLOCOCCUS AUREUS 01MAR79 - 31AUG79
C S F

	NR	SENS	MOD	RES
PENICILLIN	3	.00	.00	100.00
OXACILLIN	3	100.00	.00	.00
ERYTHROMYCIN	3	100.00	.00	.00
CEPHALOTHIN	3	100.00	.00	.00
KANAMYCIN	3	66.67	.00	33.33
GENTAMICIN	3	66.67	.00	33.33
CEFOXITIN	2	100.00	.00	.00
CEFAMANDOLE	2	100.00	.00	.00
CEPHRADINE	2	100.00	.00	.00

STAPHYLOCOCCUS AUREUS 01MAR79 - 31AUG79
DRAINAGE

	NR	SENS	MOD	RES
PENICILLIN	106	11.32	.00	88.68
OXACILLIN	106	100.00	.00	.00
ERYTHROMYCIN	106	95.28	.94	3.77
CEPHALOTHIN	107	100.00	.00	.00
KANAMYCIN	107	78.50	.00	21.50
TETRACYCLINE	1	100.00	.00	.00
AMPICILLIN	2	50.00	.00	50.00
COLISITIN	1	100.00	.00	.00
CHLORAMPHENICOL	3	100.00	.00	.00
GENTAMICIN	107	85.05	.00	14.95
CEFOXITIN	32	100.00	.00	.00
CEFAMANDOLE	32	96.88	3.12	.00
CEPHRADINE	32	93.75	3.13	3.13

Figure 15. An example of the Antibiotic Susceptibility Profile Report, sorted according to organisms and specimen sites, used at the U. of A. Hospital, is shown here.

data has formed the basis for establishing criteria between antibiotic susceptibility patterns and identification of organisms in his system. An example of a computer-generated histogram for comparing the zone sizes of 356 strains of *Staphylococcus aureus* is shown in figure 16.

Infection Control Reports

Computer-reports for infection control surveillance range from the Medlab system's simple listing of positive culture results, to tabulations of the incidence of infections as in the reports described by Barlett (1975), to the more sophisticated surveillance reports described by Ryan (1979) that also print out various additional factors on patients (such as presence of catheters, leukemia, etc.) which are sorted in various ways to allow analysis. Also available are commercial computer services, such as the Bac-Data infecton control service provided by Medical Information Systems Inc[2]. These services process bacteriology culture result data submitted by hospitals to derive various infection statistical reports both for the particular hospital and for the whole nation.

However, since the data used in most of these systems are based on **isolates** rather than **actual infections**, careful interpretation of these reports is necessary, otherwise they could erroneously lead to the conclusion that an outbreak had occured when in fact multiple isolates had been received from the same patient.

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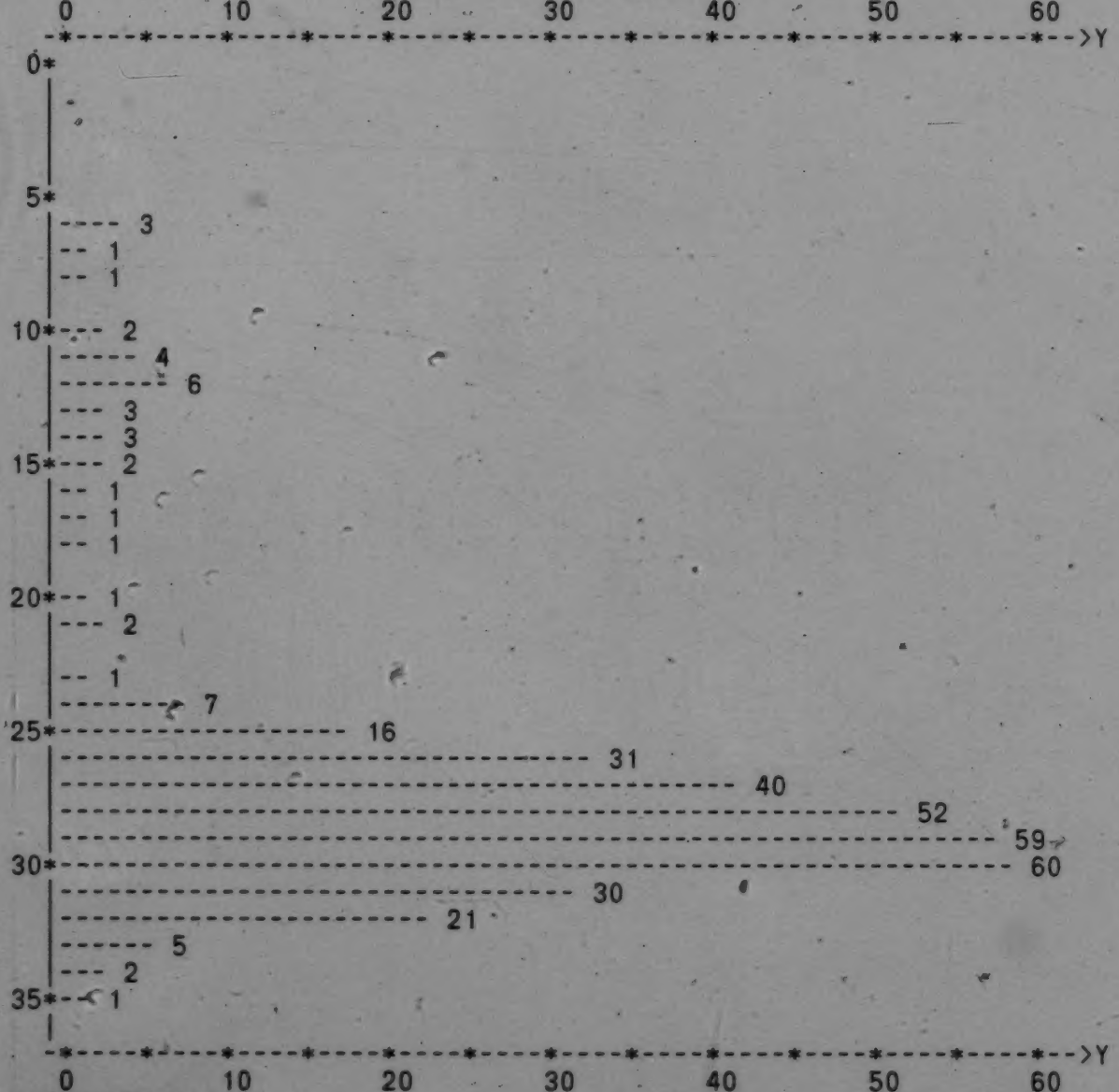
[2]Address: Division of Fish-Stevens Inc. 120 Brighton Rd., Clifton, New Jersey 07012.

Figure 16. Computer-generated histogram of zone sizes occuring in tests of susceptibility of 356 strains of Staphylococcus aureus to erythromycin used at the Massachusetts General Hospital. Quoted from page 190 of 'Role of computer in microbiology'. By I. Kunz. In 'Modern methods in medical microbiology - systems and trends'. By J. E. Prier, J. Bartola, H. Friedman. 1976. University Park Press.

KIRBY-BAUER PROFILES AUG 18 - SEPT 17 1971
STAPH AUREUS
ERYTH (14-17)

356 TESTS
X-AXIS=ZONE SIZE IN MILLIMETERS
Y-AXIS=NO. OF ISOLATES



X-INCREMENT= 1
Y-INCREMENT= 1

Brief descriptions of some of the more common types of infection control reports are given as follows:

Infection Summary Report

These reports are usually generated at regular intervals or upon request. They contain the results on certain specimens that were positive for a particular organism. Most commonly the reports are sorted by various parameters, such as organism names, hospital locations, specimen types/sources, date of cultures, etc., in the order specified by the user. Examples of these reports from the Royal Alexandra Hospital (Lau 1979) and Bexar Hospital District (Jorgensen 1978) are shown in figures 17 and 18, respectively.

Organism Cluster Report

One of the infection control reports produced by the Microbiology Department at the University of Alberta Hospital is an *organism cluster report* which shows the number of various organisms isolated during a specified time period on various stations. An example of this report is shown in figure 19. This report is particularly useful in that one can easily detect any increase in the number of a particular organism on certain stations during the specified period. Unfortunately, at present, this report is only generated in batch mode once every six months. Hence, the analysis is retrospective in nature and is rarely useful for short-term problems.

ROYAL ALEXANDRA HOSPITAL

INFECTION SUMMARY REPORT FROM 7/ 6/1979 TO 7/ 7/1979 PAGE 1

ORGANISM	LOCATION	SPECIMEN	BODY SITE	PATIENT ID	ISOLATES
ESCHERICHIA COLI	62	URINE-MIDSTREAM		197008	1
	63	SPUTUM		746357	1
		URINE-MIDSTREAM		456378	2
	64	AUGER SUCTION		364572	1
		SPUTUM		364572	2

SPECIMEN	BODY SITE	ORGANISM	LOCATION	PATIENT ID	ISOLATES
SPUTUM		PSEUDOMONAS AERUGINOSA	36	584721	1
SWAB	THROAT	PSEUDOMONAS FLUORESCENS	36	574621	1

LOCATION	SPECIMEN	BODY SITE	ORGANISM	PATIENT ID	ISOLATES
47NICU	ENDOTRACHEAL		STAPHYLOCOCCUS EPIDERMIDIS	574638	1
			STREPTOCOCCUS FECALIS	478367	1
	SWAB	EAR RIGHT	BACTEROIDES SPECIES	574634	1
			PEPTOCOCCUS SPECIES	574634	1
48	AMNIOTIC FLD		STREPTOCOCCUS FECALIS	493857	2
			ESCHERICHIA COLI	574873	1
	SWAB	VAGINAL	GRP A STREPTOCOCCUS	796584	1

Figure 17. Examples of the Infection Summary Report, sorted according to different parameters, are shown here.

05/18/76 BEXAR COUNTY HOSPITAL DISTRICT PAGE 2

MBR105 DAILY EPIDEMIOLOGIC REPORT

ROOM-BED	PATIENT	G-NR	ADM-DATE	ADMIT DIAGNOSIS	LOG-DATE	SPECIMEN	QUANT	?ORGANISM
0550-01	WILLIAMS, MICHAEL	416852	05/13/76	ACUTE APPENDICITIS NOS				
0550-02	AVERY, HUBERT J.	472545	04/23/76	POISON VENOM				
0550-01	WILLIAMS, MICHAEL	416852	05/13/76	ACUTE APPENDICITIS NOS	05/14/76	BDY FLUID, PERITONEA	HG	?E COLI
							HG	?P AERUGINOSA
0550-02	AVERY, HUBERT J.	472545	04/23/76	POISON VENOM	05/15/76	EXUDATE, WOUND	HG	S AUREUS
0550-02	AVERY, HUBERT J.	472545	04/23/76	POISON VENOM	05/16/76	EXUDATE, WOUND	HG	S AUREUS
0556-01	LINDSEY, BG	473401	05/02/76	PRENATAL CARE, NORMAL				
0556-02	LINDSEY, BG	473401	05/02/76	PRENATAL CARE, NORMAL	05/15/76	BDY FLUID, HAF.FLD.	R OTH	GM POS GROWTH
0616-01	BABBS, JOE	020443	05/16/76	LACERATION CHEST WALL				
0616-02	TEAP, ALVIN	206371	04/13/76	HEPATITIS NEC & NOS				
0616-03	FOREST, ROBERT P.	276141	05/04/76	EENTEROSTOMY COMPLICATION				
0616-04	GUERRA, JUAN	296442	05/09/76	LACERATION ARM NOS				
0616-03	FOREST, ROBERT P.	276141	05/04/76	ENTEROSTOMY COMPLICATION	05/16/76	BLOOD, BLOOD		AEROBIC BOTTLE:
								GM POS COCCI
0623-02	HOLLAND, MARCIE	245515	05/16/76	LACERATION NOS				
0623-02	FLORES, LILA	297187			05/15/76	EXUDATE, R-FOOT	HG	S AUREUS
							HG	?GRP A 'STREP
0632-01	MCGEE, JOHN	469319	05/16/76	GALLBALDDER CALCULUS				
0632-02	CROW, WILLIAM A.	467878	05/06/76	VOMITING				
0632-03	DONLEY, JAMES F.	091688	04/04/76	MISSING OR INVALID DIAGNOSIS				
0632-04	ROBERTS, FRANK	372707	05/15/76	RESO UBSYFFUCUEBCY NOS				
0632-02	CROW, WILLIAM A.	467878	05/06/76	VOMITING	05/14/76	SPUTUM, SPUTUM	HG	?S PNEUMONIAE

Figure 18. A daily epidemiologic report used by the hospital infections control officer that indicates patients with organisms of epidemiologic interest and includes the names, room numbers, and admission diagnoses of other patients located in the same room. Quoted from page 612 of 'Computerization of a hospital clinical microbiology laboratory' by J.H. Jorgensen et.al. 1978. Am. J. Clin. Pathol. 69:6 605-614.

228/00000 AS OF 11SEP79 TO 1000

UNIVERSITY OF ALBERTA HOSPITAL

0000,790911-2123

REPORT 8301 OCCURENCE OF ORGANISMS BY LOCATION
01MAR79 - 31AUG79

PAGE 1

LOC.	ST AU	ST EP	GRDST	E COL	ENT SP	KLB SP	SER	P MIR	P IND+	P AER	ACIN	OT N-F	H-INF	CIT	OTH
01	2	13		1			3				3				9
02	54	17	13	13	13	23	8	2	17		4	19	5		19
03	36	70	24	40	11	20	8	8	2	8	2	5	14		23
04	34	26	3	24	12	28	6	10	4	19	1	4	43	3	25
06	65	28	19	59	5	15	6	1	4	20	1		5	4	23
07	14	26	21	32	1	15		5	5	8	2	4	4	7	8
08	21	18	6	19	4	15	2	5	4	10		6	3	7	
09	16	19	2	8	1	3	1	7		3	1	2	2	1	9
14	6	2		4	2	1		1		1		2			2

Figure 19. An example of the organism cluster report used in the Microbiology Dept at University of Alberta Hospital is shown here. In the table, the total number of each major type of organisms isolated on each station during a specified period are given in this table. Explanatory notes: LOC - locations; ST AU, ST EP, etc., are abbreviations for organism names.

Infection Incidence By Service/Dept

Periodically one can tally the incidence of infections within the hospital by dividing the number of patients that had developed an infection by the number of patients that were in the hospital during the same period. This is frequently expressed in percentage. In addition, one may further divide the incidence by the service or department and/or the type of infection within the hospital. An example of this type of report described by Barlett (1975) is shown in figure 20.

Barlett has also described another surveillance report in which the prevalence of various organisms isolated are listed in decreasing order for each type of infection within a particular service. An example of this report is shown in figure 21. Such data have been claimed to be very helpful in guiding physicians in the prevention and treatment of various infections.

Infection Per Consultants

Roberts (1979) has described a surveillance technique in which a computer-report is generated on patients who had developed an infection during surgical operations by a particular surgical team. The report is sorted according to the various surgeons, whose names are in codes, and would include the culture results on the patients that had developped the infections. With this report it is possible to assess whether cross-infections and the sources of such infections

INFECTION LOCATION ANALYSIS SERVICE

DATE 09/30/72

PERIOD ENDING 09/30/72

	TOTAL PATIENTS DISCHARGED	PATIENTS WITH INFECTIONS	TOTAL NUMBER OF INFECTIONS	PATNT WITH INFEC PRES ON ADM.	INFECTIONS PRESENT ON AD	PATNT WITH HOSP ASSOC INFECTIONS	HOSPITAL ASSOCIATED INFECTIONS
MEDICINE	8427	251 (3)	317 (4)			251 (3)	317 (4)
SURGERY	7079	378 (5)	491 (7)			378 (5)	491 (7)
OBSTETRICS	3564	38 (1)	41 (1)			38 (1)	41 (1)
PEDIATRICS	3311	15 ( )	15 ( )			15 ( )	15 ( )
EYE-EAR-NOSE	1192	3 ( )	3 ( )			3 ( )	3 ( )
NEUROSURGERY	1278	116 (9)	164 (13)			116 (9)	164 (13)
ORTHOPEDICS	2168	72 (3)	90 (4)			72 (3)	90 (5)
UROLOGY	2050	78 (4)	93 (5)			78 (4)	93 (5)
GYNECOLOGY	4106	155 (4)	166 (4)			155 (4)	166 (4)
ALL SERVICES	33175	1106 (3)	1380 (4)			1106 (3)	1380 (4)

Figure 20. An example of an infection incidence report used at Hartford Hospital in Connecticut is shown here. Quoted from page 101 of 'Medical microbiology - quality cost and clinical relevance' by R. Bartlett. 1974. Published by John Wiley & Sons Co. Ltd.

HOSPITAL ASSOCIATED INFECTIONS

MEDICINE

DATE 09/30/72 PAGE 1

RESPIRATORY INFECTIONS

ETIOLOGY	CASES
UNKNOWN	29
KLEBSIELLA	21
PSEUD AERUG	11
S. AUREUS	8
E. COLI	6
ENTEROBACTER	5
PROTEUS	5
D. PNEUMONIAE	5
SERRATIA	3
H. FLU	1
STREP PYOGENES	1
TOTALS	97

SEPTICEMIAS

ETIOLOGY	CASES
E. COLI	12
ENTEROBACTER	7
PSEUD AERUG	6
KLEBSIELLA	5
S. AUERUS	4
SERRATIA	3
S. EPIDERM	2
STREP FECALIS	2
PROTEUS	1
BACTEROIDES	1
D. PNEUMONIAE	1
STREP PYOGENES	1
MICRO ANAER	1
TOTALS	46

Figure 21. Portions of the surveillance report of hospital associated infections used at the Hartford Hospital. Note the arrangement by computer of etiologic agents in descending order of frequency. Quoted from page 103 of 'Medical microbiology - quality cost and clinical relevance'. Raymond. Bartlett. 1974. Published by Jon Wiley & Sons Co.Ltd.

could be identified at an early stage. An example of this report is shown in figure 22.

Analysis of Swab Data. Consultant A. Period Jan.1978.

Name1	01.01.78	Throat-Nose	Strep.Haem	Ward:01
Name2	01.01.78	Pus	Coliform	Ward:01
Name3	01.01.78	Urine	Coliform	Ward:01
Name4	03.01.78	Pus	Bacteroid	Ward:01
Name5	16.01.78	Urine	Proteus	Ward:01
Name6	24.01.78	Pus	Staph.CPos	Ward:02
Name7	05.01.78	Urine	Coliform	Ward:02
Name8	07.01.78	Pus	Coliform	Ward:02
Name8	10.01.78	Pus	Pyocy	Ward:02
Name8	14.01.78	Sputum	Pyocy	Ward:02

Analysis of Swab Data. Consltant B. Period Jan.1978.

Name9	04.01.78	Urine	Coliform	Ward:01
Name10	05.01.78	Urine	Coliform	Ward:01
Name11	13.01.78	Urine	Staph.CPos	Ward:01
Name12	14.01.78	Pus	Strep.Haem	Ward:01
Name13	14.01.78	Urine	Staph.CNeg.	Ward:01
Name14	04.01.78	Urine	Coliform	Ward:02
Name15	13.01.78	Other	Klebsiella	Ward:02
Name16	13.01.78	Pus	Coliform	Ward:02

Analysis of Swab Data. Consultant C. Period Jan.1978.

Name17	02.01.78	Pus	Coliform	Ward:01
Name18	03.01.78	Urine	Other	Ward:01
Name19	09.01.78	Urine	Coliform	Ward:01
Name19	13.01.78	Urine	Coliform	Ward:01
Name20	02.01.78	Other	Other	Ward:02
Name21	02.02.78	Other	Mixed	Ward:02

Figure 22. Positive growths reported from culture specimens originating from the General Surgical Wards at the Royal Lancaster Infirmary. Quoted from page 31 of 'A simple data-processing system for the monitoring of cross-infection in a district general hospital'. By J.Kelly, J.Roberts, and P.W.Harvey. 1979. Med. Inform. 4:1 : 29-34.

III. THE MEDLAB MICROBIOLOGY REPORTING SYSTEM AT THE ROYAL ALEXANDRA HOSPITAL: A CASE STUDY

A. INTRODUCTION

The microbiology reporting system to be described here is part of the Medlab computer system currently used at the Royal Alexandra Hospital in Edmonton, Alberta. This Medlab system[3] is a commercially packaged on-line laboratory computer system which includes both the operating programs and the necessary hardware.

The 1000-bed Royal Alexandra Hospital is composed of an Active Treatment Pavilion, a Children's Pavilion, and a Women's Pavilion. It admits an average of 37,000 patients per year. In addition, it also provides laboratory services to the adjacent Glenrose Hospital and several out-patient clinics.

The Microbiology Department is divided into a Bacteriology section and a Serology section, and it processes an average of 50,000 specimens per year. The department also participates in the hospital infection control surveillance program by performing periodic environmental surveillance cultures and sterility testings.

The Pathologists first decided in the winter of 1974 to computerize the laboratory in order to improve the laboratory services. The objectives of computerization are as follows:

---

[3]Address: Salt Lake City, Utah, United States.

1. To provide doctors with up-to-date patient reports in an efficient manner.
2. To provide a better patient information recording and retrieval system for the laboratory.
3. To assist in the management of the laboratory by providing computerized workload statistics.
4. To generate infection control statistical reports for the Department of Microbiology.

Although the Medlab computer was a packaged system, various specifications still had to be provided so it would be suitable for the laboratory's use. The actual implementation of the system began in the winter of 1977. After over half a year of preparation, the system went 'live' on October 23, 1978. Departments served include Microbiology, Hematology, and Clinical Chemistry, with Blood Bank to follow in the future.

So far, the system has been in operation for over two years. Various organizational and operational aspects of the system are constantly reviewed and upgraded in hoping that the services it is providing for the medical staff can be further improved. Plans for the near future include: expanding the system's core memory and storage capacities, increasing the number of input devices, and computerizing the Admitting Department.

B. MATERIALS & METHODS

Computer Equipment

The Medlab system uses the CDC 1784 series Central Processing Unit (CPU) with a core memory of 128K bytes which may be further expanded to 512K bytes.

Three CDC SMD magnetic disc drive units, each fitted with 80 mega-byte disc pack, are used for bulk data storage. IBM magnetic tapes are used to store permanent records. Two CDC 2240 high speed line printers, each capable of printing 400 lines per minute, are used for printing various reports.

For data input, there are two Hewlett-Packard mark-sense card readers. There are also a number of cathode-ray-tube consoles (CRT's) located throughout the laboratory. A remote CRT console has been installed in the Intensive Care Unit. Low speed line printers have also been installed in the Neonatal Intensive Care Unit, the Emergency Unit, and the Intensive Care Unit.

In the Department of Microbiology, there are two CRT consoles and one mark-sense card reader for test requesting and result entry. In addition, there is a DecWriter teletype terminal for printing adhesive specimen labels.

Computer Language and Files

The computer programs used in this system are part of the CDC Extended Memory System Time Sharing Monitor (Version 89.35). They are written in Fortran and set up as a data base system. This means that all the files in the system are logically related and all data access must be through a

supervisor routine called the 'data base manager'.

Most microbiology data used in reporting are pre-defined and stored in the computer. Specifically:

1. Coded words, or ASCII characters, are used to define most specimen types and body sites encountered in the Microbiology Department. These are stored in two separate files known as the Specimen File and the Body Site File. Examples of the Body Site File and Specimen File are shown in figures 23 and 24, respectively.
2. All microbiology terminologies, smear phrases, and common comment phrases are stored in a dictionary file called the Bacteriology Nomenclature File. Each phrase is accessible by a numeric code which is also the search key for that particular phrase on disc. Portions of the Bacteriology Nomenclature File are shown in figure 25.
3. Names of all the antibiotics tested in the laboratory are stored in the Antibiotic File. They are arranged in the same sequence as the micro-dilution minimal inhibitory concentration (MIC) panels that are used in the department. Each antibiotic is accessible by an unique index number. Portions of the Antibiotic File are shown in figure 26.
4. Each test procedure that can be ordered by doctors is set up as a methodology, given an 8-character test code, and assigned a numeric test code index. The methodology contains the reporting name, the work units of that test, and its reporting format. The test code or the

```
  FILE   BODFIL.RA              16:41   30 JUL 1979
*************************************************************

    1       /ABD   /    &('ABDOMEN')
    2       /ABAB  /    &('ABSCESS ABDOMINAL')
    3       /ABBA  /    &('ABSCESS BARTHOLIN')
    4       /ABBR  /    &('ABSCESS BRAIN')
    5       /ABMA  /    &('ABSCESS MANDIBLE')
```

Figure 23. Portions of the Body Site File used in the Medlab laboratory computer system at the Royal Alexandra Hospital are shown here.

```
  FILE   SPEC.RA                16:41   30 JUL 1979
*************************************************************

    1       /AB/        &('ABD FL')
    2       /AM/        &('AMNIOT')
    3       /AV/        &('AMNVAG')
    4       /AR/        &('ARTERIAL TIP')
    5       /AT/        &('ASCITIC')
```

Figure 24. Portions of the Specimen File used in the Medlab laboratory computer system at the Royal Alexandra Hospital are shown here.

M I C R O B I O L O G Y D I C T I O N A R Y

****

DICT NO	PHRASE
41	MODERATE GRAM POSITIVE COCCI IN CHAINS
42	MANY GRAM POSITIVE COCCI IN CHAINS
43	GRAM POSITIVE COCCI IN CLUSTERS
44	RARE GRAM POSITIVE COCCI IN CLUSTERS
45	FEW GRAM POSITIVE COCCI IN CLUSTERS
566	CITROBACTER SPECIES
567	CITROBACTER FREUNDII
568	CITROBACTER DIVERSUS
569	KLEBSIELLA OXYTOCA
570	KLEBSIELLA SPECIES
571	KLEBSIELLA PNEUMONIAE
760	POSSIBLE ANAEROBIC ORGANISM OBSERVED
761	NO ANAEROBIC ORGANISM OBSERVED
762	MULTIPLE SPECIES PRESENT
763	ORGANISM SENT TO PROVINCIAL LABORATORY
865	SENSITIVE TO AMPICILLIN.
866	INTERMEDIATE TO AMPICILLIN
867	RESISTANT TO AMPICILLIN
868	SENSITIVE TO CARBENICILLIN
869	INTERMEDIATE TO CARBENICILLIN
870	RESISTANT TO CARBENCILLIN
871	SENSITIVE TO CEPHALOTHIN

Figure 25. Portion of the Bacteriology Nomenclature File is shown here.

index is the name/number referred to when one wishes to request a test. At present, a separate methodology has been set up to accomodate each of the most common types of specimens encountered. Also, a separate anaerobic methodology has been created for each common type of specimen that would usually require an anaerobic culture. As a result, there are approximately 250 methodologies present in the system. Examples of some of the test codes are shown in figure 27.

Input Modes

In this system, data can be entered either by the CRT or mark-sense card mode:

Mark-sense Card Mode

There are ten different card types that are used for test requesting and result entry. The names of these cards are given in figure 28. The characteristics of some of these cards are summarized as follows:

1. Most bacteriology requests are processed through the microbiology test request card. This card has been designed to reject certain errors such as request for anaerobes on skin swabs, or cultures on a scotch tape preparation, etc. An example of the microbiology test request card is shown in plate 6.
2. The smear & culture result card and the anaerobic result card allow the entry of the most common organism results, gram smear phrases, and 'no growth' comments, etc. A unique feature of these

```
FILE   ANTI.RA                              7:48    4 AUG 1979
*************************************************************

     1        /1/          160    &('CLINDAMYCIN')
     2        #18          160    &('ERYTHROMYCIN')
     3        #35          160    &('METHICILLIN')
     4        #52           40    &('PENICILLIN')
     5        #69           80    &('AMPICILLIN')
     6        #86          640    &('CEPHALOTHIN')
     7        #103         160    &('GENTAMICIN')
     8        #120         160    &('TETRACYCLINE')
     9        #137         160    &('CHLORAMPHENICOL')
```

Figure 26. Portion of the Antibiotic File is shown here. The number with an '#' to its left is the disc address whereas the number to its right is used to derive the MIC concentration values.

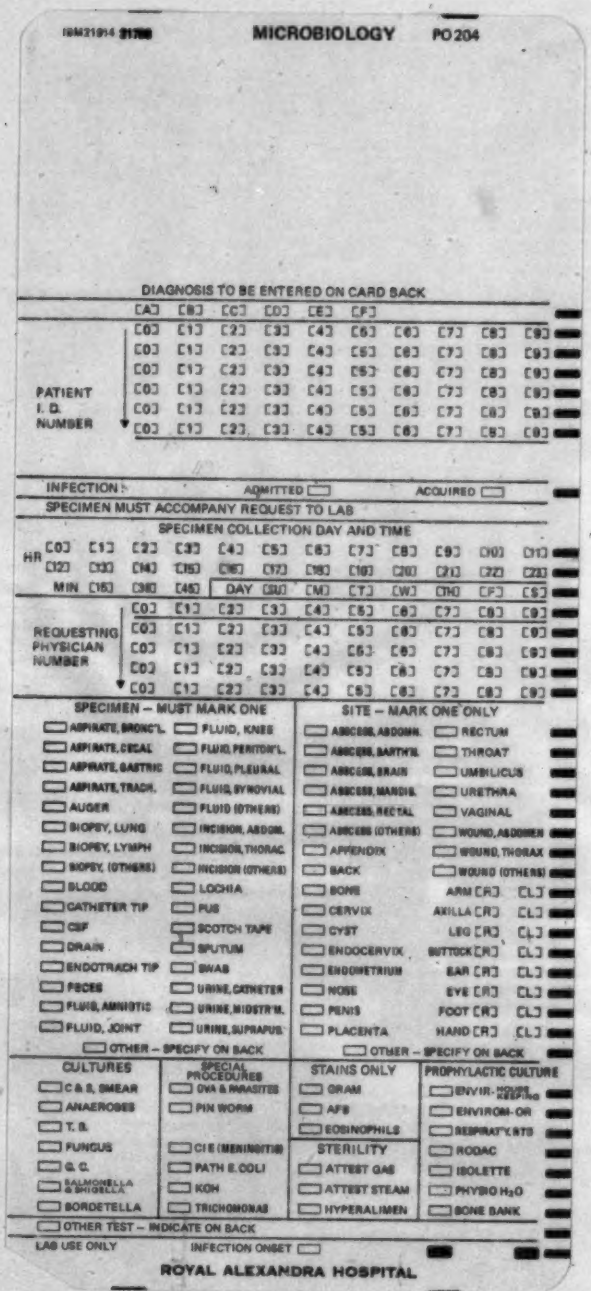
```
   INDEX       TEST CODE          REPORTING NAME
*************************************************

     5          UROC005            URINE SCREEN
     6          UROM006            URINE SCREEN
     8          SPUT008            CULT & SENS
    12          AUGER012           CULT & SENS
    14          TRAC012            CULT & SENS
    15          BLOD015            CULT & SENS
    17          XBLOD017           ANAER C & S
```

Figure 27. Examples of some of the test codes and their reporting names are shown here.

1. Microbiology test request card
2. Smear & culture result card
3. Anaerobic result card
4. MIC susceptibility result card
5. Kirby-Bauer susceptibility result card
6. TB & Mycology result card
7. Virology request card
8. Virology result card
9. Fluids request card
10. Serology request card

Figure 28. Names of the different card types used at the Royal Alexandra Hospital are listed here.


ISM21914 21788 MICROBIOLOGY PO 204

DIAGNOSIS TO BE ENTERED ON CARD BACK

[A] [B] [C] [D] [E] [F]

PATIENT I. D. NUMBER

INFECTION: ADMITTED ACQUIRED

SPECIMEN MUST ACCOMPANY REQUEST TO LAB

SPECIMEN COLLECTION DAY AND TIME

HR [0] [1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16] [17] [18] [19] [20] [21] [22] [23]

MIN [15] [30] [45] DAY [SU] [M] [T] [W] [TH] [F] [S]

REQUESTING PHYSICIAN NUMBER

SPECIMEN – MUST MARK ONE

- ASPIRATE, BRONC'L.
- ASPIRATE, CECAL
- ASPIRATE, GASTRIC
- ASPIRATE, TRACH.
- AUGER
- BIOPSY, LUNG
- BIOPSY, LYMPH
- BIOPSY, (OTHERS)
- BLOOD
- CATHETER TIP
- CSF
- DRAIN
- ENDOTRACH TIP
- FECES
- FLUID, AMNIOTIC
- FLUID, JOINT
- FLUID, KNEE
- FLUID, PERITON'L.
- FLUID, PLEURAL
- FLUID, SYNOVIAL
- FLUID (OTHERS)
- INCISION, ABDOM.
- INCISION, THORAC.
- INCISION (OTHERS)
- LOCHIA
- PUS
- SCOTCH TAPE
- SPUTUM
- SWAB
- URINE, CATHETER
- URINE, MIDSTR'M.
- URINE, SUPRAPUB.
- OTHER – SPECIFY ON BACK

SITE – MARK ONE ONLY

- ABSCESS, ABDOM.
- ABSCESS, BARTH'S
- ABSCESS, BRAIN
- ABSCESS, MANDIB.
- ABSCESS, RECTAL
- ABSCESS (OTHERS)
- APPENDIX
- BACK
- BONE
- CERVIX
- CYST
- ENDOCERVIX
- ENDOMETRIUM
- NOSE
- PENIS
- PLACENTA
- RECTUM
- THROAT
- UMBILICUS
- URETHRA
- VAGINAL
- WOUND, ABDOMEN
- WOUND, THORAX
- WOUND (OTHERS)
- ARM [R] [L]
- AXILLA [R] [L]
- LEG [R] [L]
- BUTTOCK [R] [L]
- EAR [R] [L]
- EYE [R] [L]
- FOOT [R] [L]
- HAND [R] [L]
- OTHER – SPECIFY ON BACK

CULTURES

- C & S, SMEAR
- ANAEROBES
- T. B.
- FUNGUS
- G. C.
- SALMONELLA & SHIGELLA
- BORDETELLA

SPECIAL PROCEDURES

- OVA & PARASITES
- PIN WORM
- C I E (MENINGITIS)
- PATH E. COLI
- KOH
- TRICHOMONAS

STAINS ONLY

- GRAM
- AFB
- EOSINOPHILS

STERILITY

- ATTEST GAS
- ATTEST STEAM
- HYPERALIMEN

PROPHYLACTIC CULTURE

- ENVIR-HOUSE KEEPING
- ENVIRON-OR
- RESPIRATORTS
- RODAC
- ISOLETTE
- PHYSIO H_2O
- BONE BANK

OTHER TEST – INDICATE ON BACK

LAB USE ONLY INFECTION ONSET

ROYAL ALEXANDRA HOSPITAL

Plate 6. An example of the microbiology test request mark-sense card used at the Royal Alexandra Hospital in Edmonton, Alberta.

cards is the ability to update organisms within the same genus to the particular species name. A maximum of four organisms is allowed on a card. However, more may be added as comments via the CRT. An example of the smear and culture result card is shown in plate 7.

3. There are two types of susceptibility cards used in the laboratory. One is the MIC card for recording results from the micro-dilution MIC panels. The other is the Kirby-Bauer card for recording direct disc-agar-diffusion sensitivity results. Only two sets of sensitivity results are allowed on each MIC card, and a maximum of three sets of results can be recorded with the Kirby-Bauer card. Examples of the MIC card and the Kirby-Bauer card are shown in plates 8 and 9, respectively.

CRT Mode

Various programs can be called up on the CRT by entering the appropriate command codes. Examples are the Test Request program, Result Entry program, Cancel program, and Comment program, etc. Once initiated, these programs display questions and wait for response. The user then enters the appropriate coded words, or numeric codes, etc., that are required by the various programs. For example, the Comment program, which allows either free-text or coded comment entries, is frequently used in the Microbiology Department in detailed description

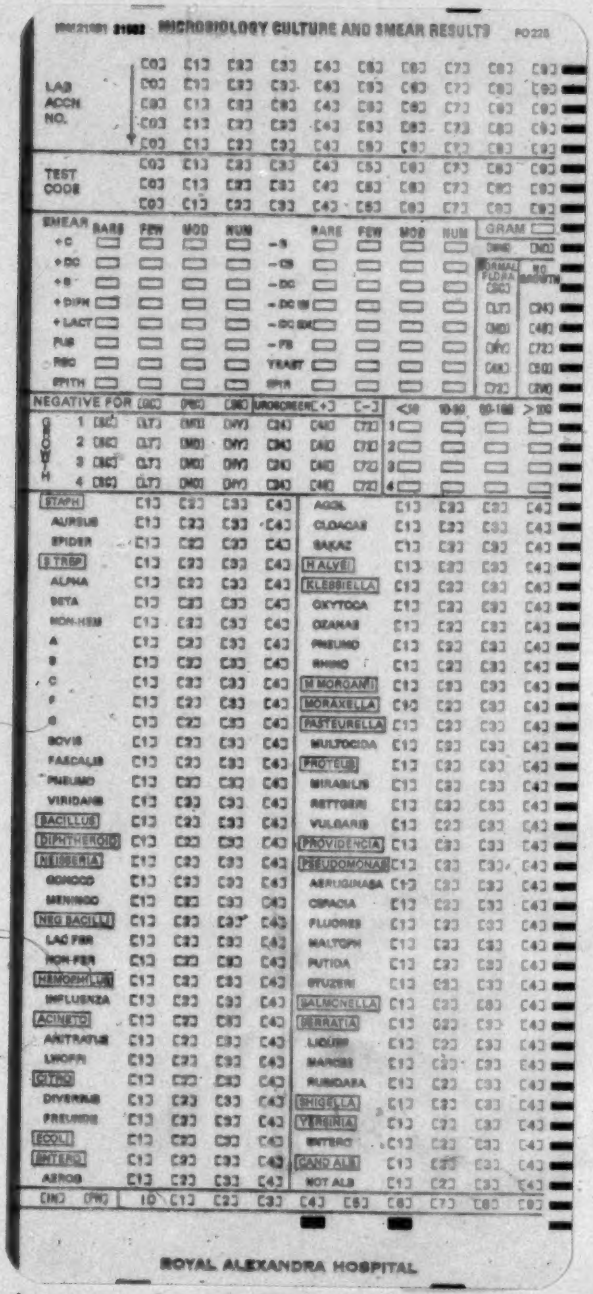


Plate 7. An example of the microbiology result entry card used at the Royal Alexandra Hospital in Edmonton, Alberta.

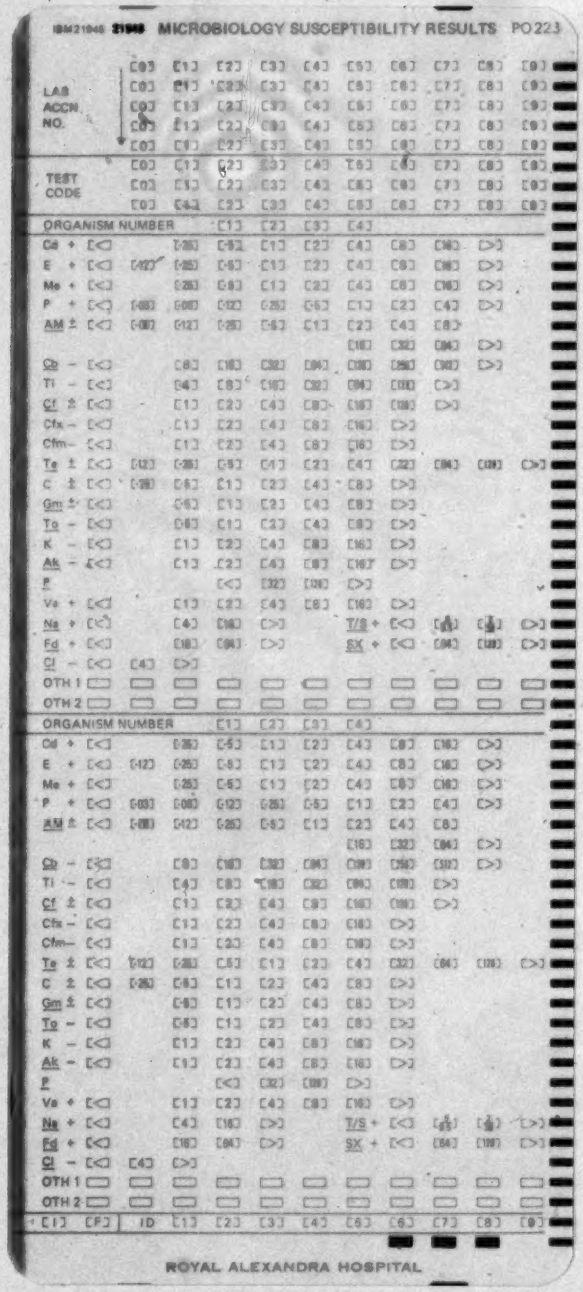


Plate 8. An example of the M.I.C. sensitivity result entry card used at the Royal Alexandra Hospital in Edmonton, Alberta.

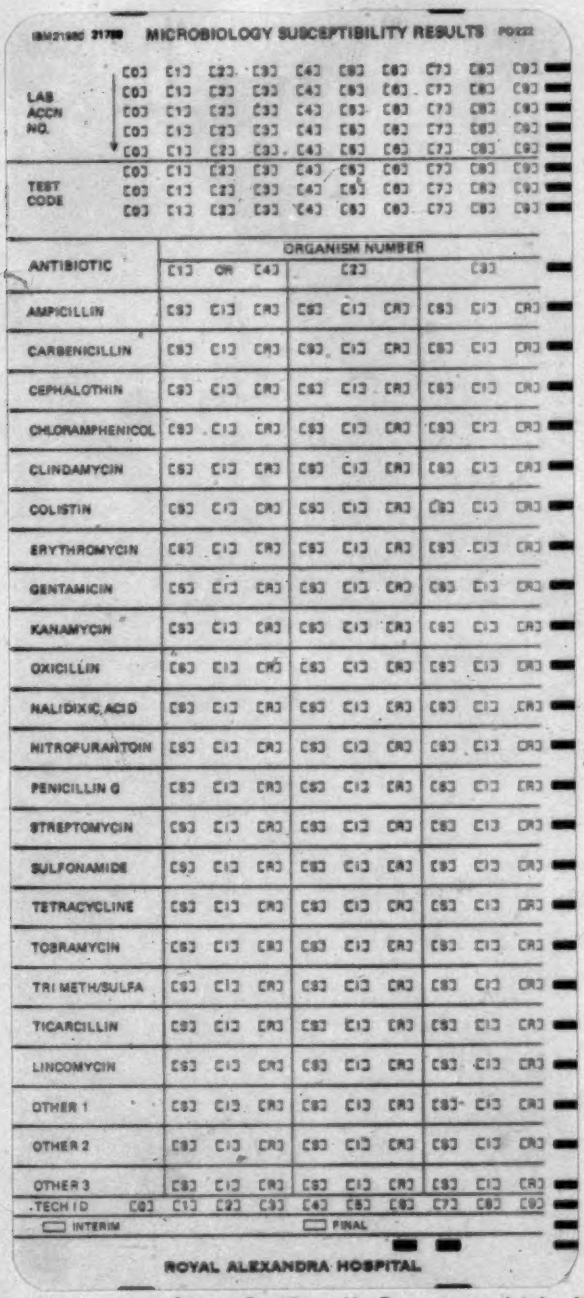


Plate 9. An example of the K.B. sensitivity result entry card used at the Royal Alexandra Hospital in Edmonton, Alberta.

of specimen types or body sites that are not defined in the files. An example of the types of questions prompted by the Test Request program is shown in figure 29.

Data Processing

Test Requesting

The RAH Microbiology Department is open from 8:00 a.m. to 4:15 p.m. seven days a week. Most specimens are brought to the Data Centre by porters or nursing staff and are then picked up by the Microbiology staff. Exceptions are STAT tests such as CSF cultures and pregnancy tests which are brought directly into the Microbiology Department. Specimens that arrive after 3:45 p.m. are refrigerated until the following day.

All Microbiology test requests and result entries are handled by the Microbiology staff. In the Bacteriology section, each specimen requested for culture must be accompanied by a microbiology request card with the appropriate information provided. Although certain error checking routines have been incorporated into the card, it is still the responsibility of the staff to ensure that each card is marked correctly before processing.

After checking for errors, the request cards are batched together and processed through the card reader. Some of the errors that are missed by the technologists will also be detected and rejected when processed through the card reader, with the appropriate error

```
TR

TEST REQUEST ENTRY              7:03    19 AUG 1979

     PATIENT ID: 123
     DR. NUMBER:

LAU, YIN YEE FRANCIS                    LAB

T: TEST TIME/DATE
R: RESULTS ENTRY
A: SPECIMEN AVAILABLE
P: PRIORITY
S: SPECIMEN TYPE
   OPTION(S): A
COLLECTION TIME, DATE (TTTT, MM/DD/YY): 0630
 TEST DONE (D): SPUT008, SPECIMEN CONTAMINATED
    SPECIMEN: SP
   BODY SITE:
 TEST/DONE (D): D

     CULT & SENS , 12671

TEST REQUEST ENTRY              7:03    19 AUG 1979

     PATIENT ID:
```

Figure 29. An example of the test request routine is shown here. Manually typed entries have been underlined to differentiate them from computer-generated sentences.

message displayed on the adjacent CRT. Those that cannot be processed by the card reader for various reasons, such as site not on card, or additional comment required, etc., are processed via the CRT console.

As soon as a request is processed, the computer will generate a set of adhesive labels with the corresponding information printed. One of the labels is then put onto the back of the original request card. This is then used as the work card for that particular culture. Since specimens are brought down continuously into the laboratory, this test request process is repeated throughout the day.

At this stage, the patient's record will indicate that this particular test has been requested and is in progress, and the patient record will remain in the computer as long as the test is still outstanding, even if the patient has been discharged.

Environmental surveillance samples are sent to the department periodically for cultures. These are entered under fictitious patients that have been admitted to fictitious locations. Then they are processed according to the established infection control protocols.

All virology cultures and viral serological studies are sent to the Provincial Laboratory of Public Health. All viral serological requests are processed by the Data Centre staff whereas the virology culture requests are handled by the microbiology staff. In both cases, the

appropriate Provincial Laboratory request forms have to be filled out and sent with the specimens. One of the computer-generated labels is then put on the back of the original request card as a temporary record.

Most Serology requests are processed by the Data Centre staff. They are usually of the 'UNAVAILABLE' type - meaning that the specimens have to be collected. After processing the request cards, these requests would appear on the collection lists along with other Hematology and Chemistry requests for collection by the blood collection team. Some requests are accompanied by specimens taken by the nursing staff. In both cases, when the specimens are available, they are brought to the Serology section.

Result Entry

All result entries require the name or index number of the test code, as well as the corresponding accession number. There are three states for a test - preliminary, interim, and final. The 'preliminary' box is marked when the technologist is working with the culture. 'Interim' is marked only when the technologist is finished with the culture and is ready to have the results finalized by the senior staff. Results on the cards are checked against the results in the computer either via the CRT or with hard-copy printouts. After verification, the senior technologists may mark the 'final' box on the cards and process the cards through the reader again for

final verification. Cultures with normal flora or no growth may be finalized by the technologists without review by the senior staff. The process is a bit illogical, but it is necessary, because once the culture results are finalized the report contents cannot be changed.

If the desired results are not on the cards, or if changes have to be made in the results that are already in the patient's record (for outstanding tests only), one can call up the Result Entry program or the Comment program on the CRT console to make the necessary changes. Listings of the Specimen File, Body Site File, and part of the Bacteriology Nomenclature File are put beside the console for quick reference. An example of the Result Entry routine is shown in figure 30.

Special tests which are not performed by the department, such as *Salmonella* typing, and *Pseudomonas* pyocine typing, etc., are sent to the Provincial Laboratory of Public Health. A comment such as 'SENT TO PROV LAB FOR FURTHER IDENTIFICATION' is then entered into the patient's record, and the cards are held un-verified until the results are returned.

Virology results may be entered either by cards or by CRTs. Only one type of results may be entered when using the viral result card. These may either be culture results, or serology results. If the desired results are not on the card, one may select the appropriate phrases

Figure 30. An example of the dialogue format in the result entry routine via the CRT in the Medlab microbiology system at the Royal Alexandra Hospital. Manually entered data has been underlined to differentiate it from computer-generated printout.

```
RE

RESULTS ENTRY PROGRAM          7:08   19 JUL 1979

     TECHNOLOGIST ID NO.: 14

     ENTRY MODE - WORKLIST OR ACCN NO. (W,A): A

        ACCN,TEST: 12671,SPUT008
  LAU, YIN YEE FRANCIS

     SPECIMEN/SITE:      SP  SPUTUM

  GRAM SMEAR
       MODERATE GRAM POSITIVE COCCI
                      31
        CHANGE, ADD, OR DELETE TEXT  (C,A,D) :

  AEROBIC CULTURE
     HEAVY GROWTH  STREPTOCOCCUS PNEUMONIAE
        732                    684
       SENSITIVE TO PENICILLIN   SENSITIVE TO TETRACYCYLINE
                  901                        904

     CHANGE, ADD, OR DELETE TEXT  (C,A,D) :

     CHANGE OR ADD SUSCEPTIBILITY FOR AEROBIC CULTURE (Y/N) :

  AEROBIC CULTURE
     MODERATE GROWTH  STAPHYLOCOCCUS AUREUS
           731                   662

     CHANGE, ADD, OR DELETE TEXT  (C,A,D) :

  SUSCEPTIBLE TO
       CLINDAMYCIN
          MIC      1.000 MCG/ML
       ERYTHROMYCIN
          MIC      2.000 MCG/ML
       PENICILLIN
          MIC      1.000 MCG/ML
       AMPICILLIN
          MIC      2.000 MCG/ML
       TETRACYCLINE
          MIC      0.500 MCG/ML

      CHANGE OR ADD SUSCEPTIBILITY FOR AEROBIC CULTURE (Y/N) :

  PRELIMINARY, INTERIM, OR FINAL REPORT (P,I,F) : P

       ACCN,TEST:
```

from the Nomenclature File, or treat the results as free-text comments, and enter them via the CRT.

Serology tests are only performed three times a week in the Serology section. Worklists can be called up prior to performing the tests in order to organize the work load for that day. All serology results are entered via the CRT. They are then printed on an 'Univerified Results Print' for verification by the senior staff. Tests that have to be repeated for various reasons may have their status changed back to 'workpool' whereas the remaining results can be verified.

Manual Backup System

Manual backup protocols have been designed to be put into effect in case of system failure. These are described briefly as follows:

1. In case of short term system shut-down, specimens are to be labeled with patient IDs and cultured. Results are marked on cards as usual but not reported. Only significant results are phoned to the stations. As soon as the system is back up, all the results are then processed.
2. When the system is shut down for 24 hours or more, results are to be recorded on the Microbiology requisitions and distributed to the nursing stations the same way as in the previous manual system. When the system is functional again, results are then transcribed onto the cards and processed at that time.

C. RESULTS OF COMPUTERIZATION

Departmental Reports

1. All requests that are outstanding in the Bacteriology section are printed on the Bacteriology Results Print every evening for viewing on the following day. The report contains all the outstanding requests along with any available results that have been entered up to the time the report is printed. It is intended to be used together with the cards that are marked 'interim' to check the results that have been entered. If there are any errors, the necessary corrections may be made via the CRT. The report also allows one to detect cultures that are overdue. An example of the Bacteriology Results Print is shown in figure 31.
2. All serology results from the Serology section have to be listed in the Unverified Results Print and examined by the senior staff before they are verified. An example of the Unverified Results Print is shown in figure 32.
3. A Department Log is generated periodically on all referral tests, such as TB and virology cultures, and viral serology tests, etc., that have been sent to the Provincial Laboratory of Public Health. This report contains the accession numbers, the names of the patients with the requests, as well as a tally on the total number of specimens sent during the specified period. An example of the Dept Log is shown in figure

```
B A C T I   R E S U L T S   P R I N T                    3:50   6 JUL 1979

ACTIVITY - BACTE GROUP2

                        **OUTSTANDING MICROBIOLOGY**

-------------PATIENT-----------   ------------------TEST REQUEST----------------

    NAME            ID    LOCATION   TEST NAME    ACC-NO      DATE   TIME    STATUS

SMITH JOHN KEN   3647382  31201      CULT & SENS  148292      7/4    100     WL POOL

**PRELIMINARY REPORT

SPECIMEN/SITE: URINE-MIDSTREAM

  GRAM SMEAR
     MODERATE GRAM NEGATIVE BACILLI
     FEW PUS CELLS

  UROSCREEN
     POSITIVE

  AEROBIC CULTURE

     >100,000 ORGANISMS/ML  GM NEGATIVE BACILLI LACTOSE FERMENTERS

     >100,000 ORGANISMS/ML  GM NEGATIVE BACILLI NON-LACTOSE FERMENTERS

     >100,000 ALPHA HEMOLYTIC STREPTOCOCCUS

LAU FRANCIS YIN  583730   51052      CULT & SENS  15512       7/4    1400    WL POOL

**PRELIMINARY REPORT

SPECIMEN/SITE: URINE-MIDSTREAM

  GRAM SMEAR
     MODERATE GRAM NEGATIVE BACILLI

  UROSCREEN
     NEGATIVE
```

Figure 31. An example of a Bacteriology Results Print used at the Royal Alexandra Hospital is shown here.

```
-------------------------------------------------------
U N I V E R I F I E D   R E S U L T S          7:21
-------------------------------------------------------

LIST NUMBER     141  ASOT    (ASOT    )

 LN   ACCN      PATIENT #      NAME                ASOT
              SP    TIME  DATE      LOCATION

 1    23177                     QC POS              NA

 2    22403                     FILL                NA

 3    11919     123456          LAU FRANCIS Y.Y.    850
              B     1720  7/15       LAB

 4    11920     876654          TEST PATIENT        <12
              B     1720  7/15       LAB

      END OF REPORT
-------------------------------------------------------
```

Figure 32. An example of an Unverified Result Print is shown here.

33.

4. The Laboratory Statistics Report is printed monthly which tallies the total number of cultures performed on each type of methodology. It also provides the total unit values per methodology. The report separates In-patients, Out-patients, Emergency patients, etc., giving the total number of cultures from each category. An example of the Laboratory Statistics Report is shown in figure 34.

Infection Control Reports

1. The Infection Summary Report that is printed every evening allows the organisms, locations, specimen types, and the body sites of all recently finalized requests to be sorted in the order that one desires. It is then viewed on the following day by the Infection Control Officer. Examples of the Infection Summary Report, sorted according to various parameters, are shown in figure 17.
2. Similarly, the Microbiology Susceptibility Report, which is printed monthly, allows the specimen types, body sites, and locations of all recently finalized requests to be sorted in any order, giving the respective susceptibility profiles of various organisms reported. This report is viewed by the Microbiologist in order to monitor the susceptibility patterns of various organisms. Examples of the Microbiology Susceptibility Report, sorted according to various parameters, are

D E P A R T M E N T L O G 8245 15 JUL 1979

ACTIVITY - MISC BACTE

DETAIL

PATIENT			TEST REQUEST					
NAME	IDENTIFICATION	ROOM	TEST NAME	ACCN	SP	DATE	TIME	STATUS	DR.NO.
DOE JOHN FRANKY	9876543	3111-2	YERSIN SEROL	11640	B	6/79	0700	WL POOL	3447
POPPINS MARY JOANNE	1234566	3111-4	GC SEROL	14352	B	5/79	0800	WL POOL	3456
JACKSON KENNY ROGER	5746351	6211-3	VIRAL SEROL	16253	B	5/79	1200	WL POOL	3456
SCHLITZ MILLER	3746251	6211-2	VIRAL SEROL	17263	B	6/79	2315	WL POOL	3456
LABATTS BLUE	2837465	5412-4	VIRAL SEROL	19283	B	4/79	2134	WL POOL	3456
HEINDERBURG JOHN R	2837465	6224-1	VIRAL SEROL	19384	B	4/79	1320	WL POOL	3447
BUDWEIZER STU	1827364	4234-1	VIRAL SEROL	10293	B	3/79	1200	WL POOL	3447
LANCASTER RONALD D	2938475	4322-4	VIRAL SEROL	11221	B	5/79	1200	WL POOL	3441

WORKLOAD SUMMARY

	---SAMPLE COLLECTION---				WORK POOL		---WORK LIST---			
	UNCOLLECTED		--LISTS--							
TEST NAME	ROUT	STAT	ROUT	STAT	ROUT	STAT	NO.	ROUT	STAT	TEST NAME
YERSIN SEROL	0	0	0	0	0	0	1	0	0	YERSIN SEROL
GC SEROL	0	0	1	0	0	0	0	0	0	GC SEROL
VIRAL SEROL	0	0	0	0	6	0	6	0	0	VIRAL SEROL

Figure 33. An example of a Department Log used at the Royal Alexandra Hospital Microbiology Dept for referral specimens is shown here.

22:05 1 AUG 1979

ALL SHIFTS

LABORATORY STATISTICS REPORT

SECTION: BACTE

	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	1978 YEAR	1979 JUL	1979 YEAR
ENTIPO39 REQUESTED AS ENTIPO39															
INPATIENTS	37	0	0	3	30	19	26	24	21	28	35	12	235	0	0
EMERG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OUTPATIENT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GLENROSE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
REFER	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H.O.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Q.C.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	37	0	0	3	30	19	26	2	21	28	35	12	235	0	0
WEIGHT	38.0														
WT.TOTAL	1406	0	0	114	1140	722	988	912	798	1064	1230	456	8930	0	0
STAT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SPUTO08 REQUESTED AS SPUTO08															
INPATIENT	263	0	0	41	220	189	246	180	197	187	180	154	1857	0	0
EMERG	2	0	0	0	3	5	6	1	3	3	5	1	29	0	0
OUTPATIENT	0	0	0	2	0	0	0	0	2	4	3	29	39	0	0
GLENROSE	3	0	0	1	3	4	6	2	1	2	4	3	29	0	0
REFER	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H.O.	0	0	0	0	0	0	0	1	0	0	1	0	2	0	0
Q.C.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	268	0	0	44	226	208	258	185	203	196	193	187	1923	0	0
WEIGHT	38.0														
WT.TOTAL	10184	0	0	1596	8664	7524	9084	6992	7638	7372	7220	6080	70374	0	0

Figure 34. An example of the workload statistics report used in the Medlab system at Royal Alexandra Hospital is shown here.

shown in figure 35.

Patient Inquiry

1. Direct on-line patient inquiries are available via the CRT to retrieve patient information that is in the computer. Selected results may be displayed on the screen for viewing or printed as hard-copy print-outs.
2. Patient records are stored in the computer as long as there are tests that are still outstanding. Once all tests are verified the patient record will be purged onto magnetic tape three days post-discharge.

   Out-patients such as those from Emergency, clinics, etc., are discharged from the computer the day after all the tests have been verified. Therefore one would have to consult the Medical Records Department in order to retrieve results on these patients.

Patient Reports

1. Patient Summary Reports are printed every evening listing all laboratory tests requested along with all results that are available up to the time before the reports are printed. These reports are cumulative for a period of seven days. On the eighth day only the outstanding requests will appear but not the requests that have been finalized during the last seven day period. These reports are used as the patients' chart reports. Each time a new report is received, the old copy is discarded, except for the seventh day report, which is retained as the permanent copy for that seven

MICROBIOLOGY SENSITIVITY REPORT FROM 7/ 6/79 TO 7/ 7/79 PAGE 1

ESCHERICHIA COLI

CEPHALOTHIN

<1.0	1.0	2.0	4.0	8.0	16.0	32.0	64.0	>64.0
0	0	1	11	4	2	0	0	0
0.0%	0.0%	5.6%	61.1%	22.2%	11.1%	0.0%	0.0%	0.0%

GENTAMICIN

<.25	.25	.50	1.0	2.0	4.0	8.0	16.0	>16.0
3	0	14	0	1	0	0	0	0
16.7%	0.0%	77.8%	0.0%	5.6%	0.0%	0.0%	0.0%	0.0%

The above option sorts on ORGANISMS only. The report lists each antibiotic in the susceptibility profile for each type of organisms isolated from all sources.

STAPHYLOCOCCUS AUREUS

AMPICILLIN

31

<.12	.12	.25	.50	1.0	2.0	4.0	8.0	>8.0
1	0	0	1	0	0	0	0	0
50.0%	0.0%	0.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%

41

<.12	.12	.25	.50	1.0	2.0	4.0	8.0	>8.0
0	0	0	0	0	1	0	0	0
0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%

The above option sorts on ORGANISMS and LOCATIONS. It lists each antibiotic in the profile for each type of organisms isolated according to locations.

KLEBSIELLA PNEUMONIAE

URINE-CATHETER SPECIMEN

CEPHALOTHIN

41

<1.0	1.0	2.0	4.0	8.0	16.0	32.0	64.0	>64.0
0	0	0	1	0	0	0	0	0
0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%

51

<1.0	1.0	2.0	4.0	8.0	16.0	32.0	64.0	>64.0
0	0	0	0	0	0	0	0	0
0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%

The above option sorts on ORGANISMS, SPECIMEN TYPES, AND LOCATIONS. The profiles are on each type of organisms isolated by specimen types and locations.

Figure 35. Examples of the Microbiology Susceptibility Report, sorted by various parameters, are shown here. Only three options are listed. A fourth option which is not listed allows one to sort by organisms, specimen types, body sites, and locations. All data are from verified results only. Numbers such as 33, 41, 51, etc., on the top of the MIC's are station location numbers.

day period. An example of a patient report is shown in figure 36.

2. Ward Summary Reports that contain all outstanding requests along with their results are printed every afternoon. These are temporary ward reports that are used to inform the medical staff of the progress of all outstanding requests and are discarded at the end of each day.
3. Environmental culture results are printed periodically and sent to the appropriate stations. Only hyperalimentations from Pharmacy, bone swab cultures from Operating Room Bone Bank, and ATTESTS from all autoclaves within the hospital are on the computer at present.

D. DISCUSSION

Test Requesting

1. All patients have to be admitted to the system before tests can be requested on them. Although most of them are admitted by the Data Centre clerks, a fair number still reach the Microbiology Department without having been admitted. Therefore they would have to be entered by the Microbiology staff. This has proven to be a time-consuming task.
2. A rough estimate has shown that only about 70% of the microbiology request cards could be processed through the card reader. The remaining 30% had to be requested

LAU, YIN YEE FRANCIS 123 M 23 LAB

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TEST	SPEC	RESULT	REQ-DATE	TIME	COL-DATE	TIME	ACCN
CULT & SENS			7/ 7/79	1737	7/ 7/79	1740	15434

**INTERIM REPORT

SPECIMEN/SITE: SPUTUM

AEROBIC CULTURE
MODERATE NORMAL BACTERIAL FLORA

HEAVY GROWTH STAPHYLOCOCCUS AUREUS
SUSCEPTIBILITY TEST

	MIC (MCG/ML)
CLINDAMYCIN	< 0.250
ERYTHROMYCIN	< 0.250
METHICILLIN	0.500
PENICILLIN	>
AMPICILLIN	> 8.000
CEPHALOTHIN	< 1.000
GENTAMICIN	< 0.250
TETRACYCLINE	8.000
CHLORAMPHENICOL	< 64.000
NITROFURANTOIN	< 0.500 / 9.50
TRIMET/SULFA	

HEAVY GROWTH BETA HEMOLYTIC STREPTOCOCCUS GROUP
SENSITIVE TO ERYTHROMYCIN
SENSITIVE TO PENICILLIN
SENSITIVE TO AMPICILLIN
SENSITIVE TO CEPHALOTHIN
SENSITIVE TO TETRACYCLINE
SENSITIVE TO CHLORAMPHENICOL
SENSITIVE TO LINCOMYCIN
SENSITIVE TO OXACILLIN

Figure 36. An example of the patient summary report is shown here.

via the CRT. This is mostly due to the specimen type or body site not being on the request card. So it appears that the CRT is essential in this process in order to allow a degree of flexibility that the mark-sense card lacks.

3. Of the four request cards that are used (virology, fluids, serology, and microbiology), the microbiology request card has presented the greatest challenge. It was hoped at first to design the microbiology request card so that certain types of specimens would only be allowed certain requests. But this has proven to be very complicated. Also, frequently the specimen types and body sites are marked arbitrarily because of the limited number of choices that are on the card. This has resulted in the loss of accuracy on the information regarding the request.
4. The fact that there are over two hundred methodologies has caused some confusion in selecting the right test code when test request is done via CRT. Often they are chosen arbitrarily because none would seem to fit the indicated specimen type exactly.
5. The time required to process a specimen has increased after computerization, because additional time is required to check the request cards for errors and to affix the adhesive labels. So there has not been any net saving in the technologists' time in this regard.
6. The Medlab system does offer the capability of

preventing duplicate request by comparing each request with the patient file and rejecting the request if a similar request has been made within a specified time period. But during implementation it was felt that this feature might actually hinder the processing of duplicate specimens that might well be justified. Also if all the tests were to be checked for duplication it was feared that the overall system response time would be affected and prolonged drastically. Therefore this particular feature was not included in the system.

Result Entry

1. Both the accession number and the test code index have to be marked on each result card before processing. This is quite time-consuming, if many cards are involved. It would be much more efficient if the accession number and test code index could be pre-printed onto the result cards by the computer.
2. In addition, marking of the card is extremely critical because partially marked boxes will not be picked up by the card reader, whereas markings that have not been erased completely can cause erroneous results to be entered un-intentionally.
3. Since it is impossible to know precisely whether the results have been picked up by the scanner or not, it is still necessary to compare the result cards with the result printouts. This process has offered little improvement over the previous manual method of checking

reports.

4. In general, mark-sense cards seem to be an adequate means to enter test results, provided that the CRT can be used to enter the less commonly encountered results. However, good co-ordination is required in using both cards and CRT's for result entry. For example, if one attempts to update an organism result by CRT and subsequently tries to process other organism results by cards for the same culture, the cards would be rejected because the organism result that has been entered via CRT is not marked on the card. Occasionally, this has resulted in some confusion, because one cannot tell exactly what results are in the computer by just examining the result cards.

Patient Reports

1. The Patient Inquiry program and its optional hard-copy print-out are invaluable because they provide direct access to all the patient results that are in the computer. The only draw-back seems to lie with the fact that most of the microbiology results are not entered until some time in the afternoon. So the medical staff would still have to phone the department to inquire results that have not yet been entered.
2. For the same reason mentioned above, the Ward Summary Reports that are printed each early afternoon have not been very useful for the medical staff in locating microbiology results.

3. Some physicians are dis-satisfied with the lengthy Patient Summary Reports that they are now receiving, since the reports start with the oldest requests in chronological order within the 7-day period and new results are not flagged, it is very difficult to find the requests that contain new results.
4. Because of the limited storage capacity with the system, certain patients, such as those from the Glenrose Hospital, Emergency, and Out-patient Clinic, etc., are purged from the system shortly after all requests have been finalized. This has resulted in some criticisms from the medical staff, because they could not retrieve these records from the system.

Statistical Reports

1. The departmental reports are useful in monitoring and organizing the work load within the Department. The Department Log, in particular, provides valuable information about the number of specimens that have been sent to Provincial Laboratory. And the Workload Statistics Report has eliminated the time and effort that are required to collect and compile the data.
2. The Infection Summary Report is especially useful because it can monitor organisms that are of epidemiological significance. However, the fact that it only sorts on finalized requests limits the survey to a retrospective view. Also, it is not possible to sort and list only selected organisms, locations, and specimen

types, thus one would have to scan through the whole printout in order to locate the information of interest.

3. The Microbiology Susceptibility Report is also useful in monitoring the susceptibility profiles of various organisms isolated during a specified period. However, a major shortcoming is the fact that each MIC column contains only the percentage of organisms that was sensitive at that concentration. It would be much more informative if the percentages could be cumulative up to the highest MIC dilution, i.e., the percentage of organisms susceptible to a particular MIC concentration would also include the percentages of the same organisms found susceptible at lower concentrations.

Overall Remarks

In retrospect, this microbiology reporting system has only partially fulfilled the objectives set out by the laboratory. Undoubtedly there has been a dramatic improvement in the accessibility of the patient results to the medical staff. Results that are so critical in the management of patients in the Intensive Care Unit, Neonatal Intensive Care Unit, etc., are now directly accessible via the remote terminals on these nursing stations. The cumulative nature of the patient reports has also allowed the physicians to monitor progress in their patients' clinical conditions easily.

But some doctors have claimed that they are still only getting the same result contents as before without any real

improvement in the service the laboratory is providing. And in some cases, the bulky reports have actually proven to be a nuisance in looking up the desired results. Although the report format could be improved somewhat to make it easier to read, it is not possible for the computer to speed up the time that is required for the processing of the specimens and cultures. So unless automated instruments are acquired and on-line terminals are installed directly on all the nursing stations for result retrieval, this problem is likely to continue without any improvement.

As for the Microbiology Department, it is quite clear that computerization has indeed brought about a drastic improvement in the filing and retrieval of patient results. What used to be time-consuming searches of patient records can now be handled easily with the computer. In addition, the computer has also increased the accuracy of the reports, and standardized the reporting of most microbiology results.

The statistical reports that are available are useful but could be more informative. For example, the Infection Control report formats could be more flexible, providing only the organisms, locations, specimens of interest instead of retrieving the complete set of data. The Workload Statistics should allow further sorting and tallying of the tests requested by parameters other than the ones available by the existing program.

The Serology section has become much more efficient since computerization. The use of worklists and CRT entry of

results has drastically improved the organization and the reporting of these test results.

System hardware has so far been quite reliable, and there have only been few occasions of unscheduled down-time. Maintenance has been adequate and inconveniences caused by machine malfunctions have only been minimal. However, software modifications have been difficult, because of the lack of on-site programmers from the Medlab company, and the additional costs associated with each change being put forth.

Despite the lack of experience in the initial designing and planning of the system, it seems that with careful re-designing and re-organization of the methodologies, test codes, specimen types, and body sites, etc., one should be able to increase the efficiency of this reporting system. Other aspects, such as the automatic reporting of negative results, quality control and automated editing of results for errors, etc., should be seriously contemplated in order to utilize more of the capabilities that are not yet realized at present.

IV. COMPUTERIZED VS MANUAL INFORMATION SYSTEMS: A COST BENEFIT REVIEW

A. COST ASPECTS

Cost Comparison Between Computerized & Manual Systems

Despite the recent decrease in the cost of computer hardware, the overall cost of laboratory computer systems is still quite high. This is mainly due to the additional programming efforts that are required to provide the necessary software for the types of applications involved in these areas. As of now, there are very few clinical microbiology laboratories that are large enough to warrant a dedicated computer system. Instead, the most common practice is to install a centralized and dedicated laboratory computer system to service the various laboratory disciplines, including the microbiology laboratory. This tends to limit the choice of a system that will handle the microbiology routines. This is especially true in the case of turn-key commercial computer systems, since many of these systems, as mentioned previously, have only limited capabilities in terms of processing microbiology data.

The expenditure needed in setting up a laboratory computer system can usually be divided into (1) the non-recurring cost of purchasing and installing the computer hardware, and (2) the annual costs of operating the system (which includes data processing staff and maintenance). If it is an in-house system, there is the added cost for the

design and development of the system. Usually these costs are included in the budget of the laboratories as a whole, therefore, the exact cost of the individual area is difficult to determine. But as indicated by Kobernick (1974), laboratory computer systems are usually expensive to purchase, install and operate.

On the contrary, the cost in maintaining a manual microbiology laboratory is relatively minimal, since one merely requires some rubber stamps, typewriters or photocopying machines, filing cabinets, and clerical staff. A summary of the various items that are required in the computer and manual systems is given in figure 37.

In addition to the capital and operating costs mentioned, there is usually an additional cost that may not be apparent at the beginning. This is the amount of overtime on the part of the laboratory staff that is required to implement the system. MacLowry (1978) has found that in implementing his Honeywell microbiology computer system, there was an initial increase of 48.3% in staff overtime during the first month of implementation over the same period in the previous year. This was followed by subsequent 27.6% and 0.4% of overtime over the next two months, with the total overtime estimated to be about 730 hours. Kobernick (1974) has also reported that an additional $12,000 to 15,000 was required for the 'one-time' overtime cost during implementation of his system. Most of the overtime costs were spent on familiarizing the staff with

	COMPUTERIZED SYSTEM	MANUAL SYSTEM
Capital cost	-hardware, includes CPU, terminals, disk & tape drives, document readers, etc. -laboratory renovation -system installation -software development (if in-house)	-rubber stamps -typewritters or xerox machines
Operating cost	-data processing staff -equipment & software maintenance -computer paper, request forms, stationery supplies	-typists, clerks -request forms & stationery supplies

Figure 37. The types of costs for a computerized and a manual system are shown here.

the computer system, and in solving unforeseen computer-related problems that had arisen during the implementation phase.

There have been very few studies carried out in determining the exact cost of a computer system for the microbiology laboratory. Those that have been reported have all concluded that the cost of a computerized microbiology system is higher than that of a manual system. For example, Goodwin (1976) has estimated from his batch-oriented port-a-punch card system, that when all the associated costs were included to derive the cost of a patient report, it costs 10.97 pence (approx. 44¢) to produce a computer report, in contrast to 10.28 pence (approx. 39¢) that was needed to produce a manual report. Other studies by Harvey (1972) and Andrews (1975) have also suggested that the cost of computerized microbiology systems were from marginally to substantially higher than manual systems. The amounts reported are summarized in figure 38. However, one should note that these figures were all obtained from the use of batch-oriented, rented central computer systems, therefore, they are not truly representative of the on-line systems that are commonly used nowadays. Although it is unlikely that these on-line systems would be any cheaper to purchase and operate, there is little evidence yet reported in recent literature.

Turn-key vs In-house Systems

One of the most difficult decisions of the director of

Author	Data processing mode	Cost of one report computer	manual
Harvey (1972) Prince of Wales Hosp.	paper-tape, batch-oriented rented central computer system	77¢	75¢
Andrews (1975) Charing Cross Hospital	mark-sense document batch-oriented, rented central computer system	80¢	15¢
Goodwin (1976) North Wick Park Hosp.	punch-cards, paper-tape batch-oriented, rented central computer system	44¢	39¢

Figure 38. A summary of the cost comparison between the production of manual and computer reports in various hospitals is shown here.

a clinical microbiology laboratory regarding computer systems is whether to purchase a commercial turn-key system or to develop a customized system. Quite frequently, this can become more complicated in situations where the computer system is to be shared among other laboratory departments. Even if the director were able to make an independent selection, it is difficult to predict which would be the best choice for a given microbiology laboratory, since the final decision is affected by many factors such as: the objectives and the needs of the laboratory, the availability of suitable commercial systems for microbiology, competent programming staff who can design and develop a customized system, and most important of all, the allocated budget or funding for the proposed computer system.

Both successful in-house and turn-key microbiology systems have been reported. In general, the in-house customized systems, if properly designed and developed, can usually meet the specific needs of the user. But these systems tend to be very complicated and require highly competent programming staff in developing and maintaining the system. It is also important that the development of in-house systems should not be too dependent upon a few key individuals, since it could be disastrous to the entire project if any one of these resource persons should decide to leave the scene. In addition, the development of in-house systems would also require total committment and dedication from the laboratory staff, since implementation may be a

very demanding and exasperating process. Even after the initial implementation of the system, there will be modifications or improvements and frequently these are dependent upon the current obligations and priorities of the computing staff. Finally, it is often very difficult to assess the cost for the development of the system, since it is not always possible to predict the types of problems that one may encounter. And at least one author (Andrews 1974) has exclaimed that the development of the software for his system had taken much longer than had anticipated.

In contrast, the costs of turn-key systems are usually fairly well-defined. But since they are usually intended for general applications, any additional software and hardware for the particular laboratory would result in extra cost which can be very expensive. Furthermore, many have found (Lawrie 1979, Lau 1979) that commercial microbiology systems are usually very general in nature and require additional efforts in their adaptation to the existing microbiology routines. In some instances, the routines may have to be modifed in order to accomodate the system. Also, once the system is in operation, most vendors become reluctant to modify the software, and frequently any modifications and expansions can lead to substantial costs.

B. IMPACT OF COMPUTERIZATION IN THE MICROBIOLOGY LABORATORY

Major Shortcomings

Entry of microbiology data into the computer system is probably the main area that presents the most serious drawback. The existence of punched cards, mark-sense cards, optical reader documents, CRT's and specialized terminals, etc., seems to indicate that there is a lack of consensus as to the best means to enter these data. Also, in whatever form, data entry is usually a very time-consuming task. For example, Williams (1978) has concluded that there was no net saving in the technologists', clerks', and pathologists' time in the processing of the requests and specimens from his computerized system that uses optical reader documents and CRT's. Lawrie (1979) has also reported that the technologists' time for computer-related functions that have replaced the manual operations in his Honeywell system has actually increased by a factor of 1.3.

A survey conducted earlier by Goodwin (1976) in comparing the time it took for processing a request in both the manual and computer system has revealed that with his port-a-punch card computer system, it took an average of 11.7 minutes to process a request while the manual system only required 8.6 minutes for the same process!

Additional time and effort must also be spent in familiarizing the staff with the use of the computer in specimen and data entry, data correction and verification, and report generation, etc. Also, some individuals have to

become knowledgable about the system so they can act as the resource persons in solving computer-related problems on a daily basis. Sometimes, these can become excess burdens to the already-over-worked technologists. Unless adequate training is considered and well-planned ahead of time, the results of having improperly trained staff to operate the computer system can be disastrous.

Another serious drawback of most laboratory computer systems is unscheduled down-time, which is often un-predictable and can lead to loss of valuable time and much frustration among the staff. The exasperations and irritations caused by such occurrences, as experienced and described by Grams (1979), can severely impair the efficiency and morale of the laboratory, and could eventually lead to the destruction of the computer system. Therefore, it is most critical that there be some form of manual back-up protocols in case of such occurrences.

Aside from manual back-ups, some recent advancement in computer technology has also offered another alternative. That is, to have two or more central processors with duplicate storage devices, as in the Tandem computers described by Fenna (1980) and Grams (1979), that can in effect act as computer back-up units for each other. The data in these systems can either be updated to all units simultaneously upon entry, or in a background batch-mode at designated time. If one unit fails, the other one will be triggered either automatically or by manual start-up for

immediate replacement.

Potential Benefits

In spite of the high cost and the disadvantages associated with laboratory computer systems, it is evident that they do have much to contribute to the laboratory in terms of increasing the efficiency of the laboratory and enhancing better quality patient care. In fact, one of the major advantages of computerization in clinical microbiology is that both the quality and accuracy of patient reports can be improved dramatically. With computer-generated reports, the nomenclatures can be uniform and standardized since most results have been pre-defined. The error-checking routines that are present in some systems can automatically scrutinize results for errors without human intervention. The verification routines, as described by Lawrie (1979) and Kunz (1976), can be especially useful, since about 1/4 to 1/3 of the laboratory workload consists of these cultures and frequently they would be negative, so there can be tremendous savings in the technologists' time. Two more major benefits of computerization are the elimination of manual filing of patient reports and the instant retrieval of most test results upon inquiry.

A fourth major benefit is that the patient information that is often needed to decide on proper test procedures can now be stored in a computer-based central information repository which can be easily accessible to the laboratory staff. This will save time both for the nursing stations

requesting tests and for the technologists needing information.

With the computer system one can also take advantage of the vast amount of test result data to perform various statistical analyses and evaluations. For example, by tabulating the percentages of the susceptibility of certain organisms to various antibiotics within a specific time period, one can study the antibiotic susceptibility profiles of these organisms. With this information, physicians can make more reliable predictions about the appropriate antibiotics to use for preliminary therapy.

Infection control surveillance, a task that used to require a substantial amount of manual compilations and tabulations, can now be easily handled by the computer. For example, the computer may be programmed to perform searches of the patient records for multiple antibiotic resistant organisms that are of epidemiological significance, and also to detect any clustering of pathogens within the hospital by comparing the total number of isolates from each nursing station. Periodically, the computer can also prepare reports to provide information on the status of various hospital-associated infections for review by the infection control steering committee. With the computer assuming the laborious tasks of compiling and tabulating various infection-related data, the infection control staff can concentrate their attention and efforts on interpretation, inspection and control measures.

The computer also has much to contribute to the management and administration of the microbiology laboratory. For example, workload statistics can be tallied automatically and printed at any time upon request without additional manual effort. On a daily and weekly basis, the computer can assist in tracking down overdue patient reports and flagging positive cultures that are considered significant. In instances where billing is a major concern, as in the case with most private laboratories, the computer can assume automatic billing and can virtually eliminate the amount of charges that are usually lost due to incorrect filing of charge slips, etc. And this is one benefit which has been reported by both Jorgensen (1978) and Kobernick (1974) to be a definite measurable cost-saving feature.

C. IMPACT OF COMPUTERIZATION ON PATIENT CARE

As early as 1971 a survey conducted by Llyod Johnson Associates has concluded that computerization of clinical laboratories can lead to many benefits in the care of patients. Among those are: the reduction of the period of hospital stay for patients, more efficient use of the time of the physicians and nursing staff, and better control and maintenance of medical records.

With a computerized microbiology information system, there is less chance of confusion and misinterpretation of computer-generated patient reports by the medical staff. The cumulative nature of these reports allows much easier

correlation and also tends to minimize the effort that would otherwise have to be spent in looking up the relevant reports. The antibiotic susceptibility profile report would be able to assist physicians in selecting the appropriate antibiotics for therapy.

Because of the fact that the medical staff can get higher quality and a broader range of services from a computerized microbiology laboratory, it is possible that they may be able to reach the diagnosis sooner and begin the necessary theraputic treatments earlier, which may eventually lead to a reduction in their patients' hospital stay. But this is one aspect that is dependent upon a variety of factors and is very difficult to measure from the computerized microbiology system alone. Therefore such potential benefits are not usually readily apparent.

However, computerized microbiology information systems can improve substantially the effectiveness and efficiency of infection control protocols, thus reducing the risks of nosocomial infection outbreaks. With the annual cost of extended hospitalization due to hospital-acquired infections reported by the American Hospital Associations (1979) to be approximately 966 million dollars, such features have become highly desirable in order to control and to prevent these infections so as to contain the associated costs.

V. A PROPOSAL FOR A COMPUTERIZED MICROBIOLOGY INFORMATION SYSTEM AT THE UNIVERSITY OF ALBERTA HOSPITAL

A. INTRODUCTION

Background

The University of Alberta Hosiptal is a 1200-bed teaching hospital centre affiliated with the University of Alberta and is located in the city of Edmonton, Alberta. The Department of Microbiology within the University Hospital is staffed by 36 full-time technologists, 7 laboratory aides, 5 clerk-typists, and a laboratory scientist, and is organized into seven sections:

1. Specimen receiving and processing section, also known as mail room. Located on the 3rd floor of the clinical services wing in the hospital.
2. Miscellaneous University Hospital section. Located in Provincial Laboratory of Public Health building (Prov Lab bldg) which is next to the hospital compound. This section is further divided into several sub-sections according to the types of specimens each sub-section processes, e.g. sputums, swabs, urines, bloods, etc.
3. Antibiotics section. Located in the Prov Lab bldg and in Medical Sciences bldg.
4. Anaerobes section. Also located in the Prov Lab bldg.
5. Special non-routine diagnostic procedures section. Located at the Department of Medical Bacteriology in Medical Sciences building, which is next to the Prov Lab

Building.

6. Media & wash-up section. Located in the Prov Lab bldg.
7. Chlamydia & Mycoplasma service section in Medical Sciences Bldg.

Beside providing diagnostic service for the hospital, the department also processes selective specimens referred by the W.W.Cross Hospital, Aberhart Hospital and various regional hospitals throughout Alberta. The department also participates in the evaluation of laboratory diagnostic methods, protocols for collection & processing of specimens, and separately funded special research projects that arise from time to time. These contribute approximately 100,000 specimens that are processed annually.

In addition, the Microbiology Department is also responsible for referral of specimens from within the hospital to the Provincial Laboratory of Public Health for tests such as Syphilis and bacterial serology, TB's, Mycology and Virology cultures, etc., which amount to approximately 35,000 specimens a year.

Within the last several years, the Microbiology Department has been encountering an increasing number of problems related to the processing of microbiology test requests, specimens, and patient result data. This has been largely due to the steady increase in the department's workload over the years, which, as a result, has created great difficulties for the laboratory and medical staff in monitoring the test requests and retrieving the required

patient result data effectively. With the entire hospital expected to be relocated to the new MacKenzie Health Sciences Centre within the near future, it is anticipated that the corresponding workload will increase substantially due to the expansion in the hospital's outpatient service. This will surely enlarge the magnitude of the problems that are already present within the Microbiology Department.

In hopes of finding a solution to these problems, the department investigated into the possibility of acquiring some type of laboratory computer system to handle the patient requests and result data that are generated. However, at the time of the study, none of the commercial turnkey systems seemed entirely adequate for the tasks. So it was concluded that, instead, a customized system should be developed in order to serve the department's need.

The Tandem T16 computer, which has recently been put into operation at the University Hospital by the Computing Services Department[4], seems ideal for the development and implementation of a computerized microbiology information system, since it is expected that the Tandem computer system will eventually be extended to become a real-time centralized hospital information system, therefore, by feeding the microbiology result data directly to the centralized computer-based patient data bank, the typical interfacing that would usually be required for a laboratory

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[4]An overview of the system is presented in 'In-house integrated development at U. of A. Hospital by D. Fenna. In 'Health computer applications in Canada'. Published by Health Computer Information Bureau, 1980.

mini-computer system can be altogether eliminated.

Subsequently, as a first step, an analysis was carried out on the existing work flow within the department in order to define, specifically, the problem areas. The findings from the analysis that was carried in the summer of 1980 have been summarized as follows:

1. There is a lack of control in the initiation of microbiology requests on the nursing stations. As a result, from time to time, requests are duplicated and contain incomplete information. Also, the fact that there are many types of microbiology requisitions has created some confusion on the stations in that frequently the required requisition is missing, or the wrong type of requisition is submitted.
2. Due to the large number of specimens received daily, the task of maintaining a log of each specimen received in the laboratory, by assigning each an accession number, has become very time-consuming and grossly inadequate for patient result inquiries. The attempt to maintain a separate up-to-date log on patients in alphabetical order has also proven futile because it is too time-consuming.
3. Because of the large number of specimens that are processed, verification of results, typing and filing of patient reports, and retrieval of these results upon inquiry, have all become very laborious and time-consuming tasks.

4. With the large number of cultures it has become very difficult to detect and track down culture results that are overdue.
5. Delivery of patient reports to stations by messenger has not been entirely satisfactory. The reports are prone to misplacement, and frequently some reports miss the report pick-up deadlines and thus are further delayed in their distribution.
6. The department lacks up-to-date statistics, such as workload and infection control statistics, etc. As a result, it is difficult to carry out proper assessments on the workload and related problems within the department, and to perform effective infection control surveillance on the hospital as a whole.

Once the problems have been defined, the next step is to prepare a set of functional requirements so that the proposed computer information system can be designed, developed, and implemented accordingly. In fact, a proposal, which contains the complete functional specifications, has been completed in January of 1981. This document is intended to serve as the basis for mutual understanding between the Microbiology Department (user), and the Computing Services Department (developer) during the development of the proposed system.

The purpose of this report, then, is to describe in detail the contents of the functional specification document that has been forwarded to the Departments of Computing

Services and Microbiology. Explanations of the specifications are included throughout the report where appropriate.

Project Reference

This project has been undertaken with funding from the Dept of Medical Bacteriology at the University of Alberta. The proposals have been developed with the consultation and cooperation of the Dept of Microbiology, Division of Infectious Diseases, and the Dept of Computing Services at the University of Alberta Hospital. In particular, individuals who have actively participated in formulating the specifications for the proposed system included: J. Brunton (head of Infection Control & Antibiotics section), W. Carmichael (acting Dept chairman), M. Duhaime (lab scientist), D. Fenna (Director of Computing Services Dept), F. Jackson (Dept chairman) and the senior technologists in the Microbiology Dept.

Technical documentation relating to this project includes[5]:

1. Report samples for survey, May 1980.
2. An assessment report on the Microbiology Dept at the University of Alberta Hospital, June 1980.
3. An assessment report on the Microbiology Dept at the University of Alberta Hospital, revised version, July 1980.
4. Modes of data entry for the computerized reporting

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[5] Copies of the reports can be obtained upon request from Francis Lau, Dept of Medical Bacteriology, U. of A.

system, July 1980.

5. A proposal for a computerized microbiology reporting system at the University of Alberta Hospital. Version 1, August 1980.
6. Re: a computerized reporting system for the Microbiology Dept. at the University Hospital. Version 2, October 1980.
7. A proposal for a computerized microbiology information system at the University of Alberta Hospital. Version 2 addendum 1, October 1980.
8. Computer-checking routines reflecting current policies in Microbiology Dept, November 1980.
9. Microbiology test procedure names & specimen types commonly encountered, November 1980.
10. Microbiology nomenclature from SNOMED coding system, November 1980.
11. Proposed computer system summary for serological, antibiotic assay specimens and reports in Microbiology Dept of University Hospital. Version 3, November 1980.
12. A proposal for a computerized microbiology information system at the University of Alberta Hospital. Version 3.1, December 1980.

B. SUMMARY OF THE PROPOSED SYSTEM

Objectives

The purposes of the proposed computer information system are as follows:

1. To act as a repository that will accept test requests and results directly by some means.
2. To provide immediate access of test results to doctors as soon as they become available reducing the time delay in report distribution.
3. To provide cumulative patient reports for the doctors in an efficient and consistent manner.
4. To ensure optimal utilization of the laboratory diagnostic service by incorporating various automated control features for test requesting according to established specimen processing policies.
5. To ensure accuracy and to improve the quality of patient reports by incorporating various editing features to control errors before reports are generated. This should also reduce the time required for manual report verification by senior technologists.
6. To increase the efficiency of the department by eliminating manual filing of patient reports.
7. To assist in the management of the department by providing periodic workload statistics and other administrative reports for the administrative staff.
8. To provide various infection control statistics and antibiotic susceptibility profile reports for the Infection Control committee for monitoring hospital-associated infections.

Overall System Requirements

System Overview

1. The microbiology information system should exist as a component of the total hospital information system so that all patient data would be automatically accessible to the laboratory and nursing stations upon admission of the patients.
2. The routines that make up the information system should be modular in nature so that deletion and addition of routines will not affect the overall operation of the other modules within the system.
3. All data access must be controlled by some means, e.g. through signon ID's and passwords, etc. All entries in the system must be accompanied by the ID of the users who have entered the information for identification purposes.
4. Basic functions of the information system should include:
   a. Test requesting and printing adhesive labels.
   b. Accepting test results to be stored in the system.
   c. Editing and verifying results to ensure their accuracy.
   d. Printing patient reports for doctors.
   e. Printing statistical reports for the clinicians, department heads, and administrative staff.
5. Results should be accessible to doctors as soon as they are verified and they should remain on-line for

at least 30 to 60 days after the patient is discharged. When results are purged onto magnetic tape for permanent records, they should still be available on request through the Computing Centre.

6. There should be computer-assisted data verification routines for error control and verification of results. The control parameters should be user-defineable and changeable at any time.
7. Most microbiology results and specimen types/sources would be pre-defined and coded in some way. If possible, the coding should conform to the SNOMED coding system[6] as much as possible.
8. Patient data should be organized so that selection of data by various parameters is possible. Usually the process involves sorting data by certain parameters, tallying the data items under each parameter, determining the percentage of each parameter, and printing out the results. A typical example may be - to search all data in past two months to derive the percentage of Inpatients, age ranging from 30 to 50, with positive blood cultures growing E.coli that was sensitive to Kanamycin.

Man-Machine Interfaces

1. Cathode-ray-tube (CRT) terminals are to be used for entry of all microbiology data. Each entry should be

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[6]Systematized nomenclature of medicine Vol. I, II. second edition. By Cote A. Roger. Published by the College of American Pathologists, U.S.A. 1979.

displayed immediately for validation. In addition, error messages should be used to guide the user in correcting incorrect or invalid terminal entries.

2. The system must be set up so that it is very easy to use with minimum training required. Instructions should be available on screen where appropriate so users can interact easily with the system.
3. Data entry should be organized so that there will be little or no coding memorization required. A combination of menu-selection, expanded text, and free-text entry is suggested.
4. Complete documentation, such as operators manual, systems manual, etc., must be available in sufficient quantities so that the organization and operations of the system can be clearly and easily understood.
5. Capacity for interfacing automated instruments should be taken into consideration in order to permit the addition of such instruments in the near future.

C. DETAILED SYSTEM SPECIFICATIONS

Guide To System Descriptions

The diagrams in the following sections describe the flow of various types of data, specimens and reports in the PROPOSED system from the time when tests are requested to the time when final reports are issued to the doctors.

Please note the following conventions (Marco 1978):

1. The bubbles in the diagrams are processes that either transform data or produce reports.
2. The arrows represent the flow of the data involved between the processes and/or sources.
3. The squares represent the sources where data originate or terminate.
4. The parallel lines represent repositories of data produced through the processes.
5. The double-ring bubbles in the proposed physical system model diagrams represent man-machine interfaces.

Detailed explanations of each process are given in the 'DETAILS OF PROCESSES' section which describe the policies and procedures that are carried out within the particular process. The 'DATA DICTIONARY' section consists of explanations to all *italicized* terms mentioned in the 'DETAILS OF PROCESSES' section.

Generally speaking, two types of specimens are processed by the Microbiology Dept. These are: (1) the specimens for culture, and (2) the blood specimens for serologicial tests and antibiotic assays. For discussion purposes, the flow of these specimens has been separated into two parts, namely, the 'FLOW OF MICROBIOLOGY SPECIMENS AND REPORTS' section, and the 'FLOW OF SEROLOGICAL, ANTIBIOTIC ASSAY SPECIMENS AND REPORTS' section.

Within each section, the IDEAL policies, procedures and flow of the specimens and reports within the department are

first described. Then the domain of change is outlined to indicate the processes that are to be computerized. The proposed computer system for each section is then depicted in the physical system model diagram.

Computer Hardware Requirements

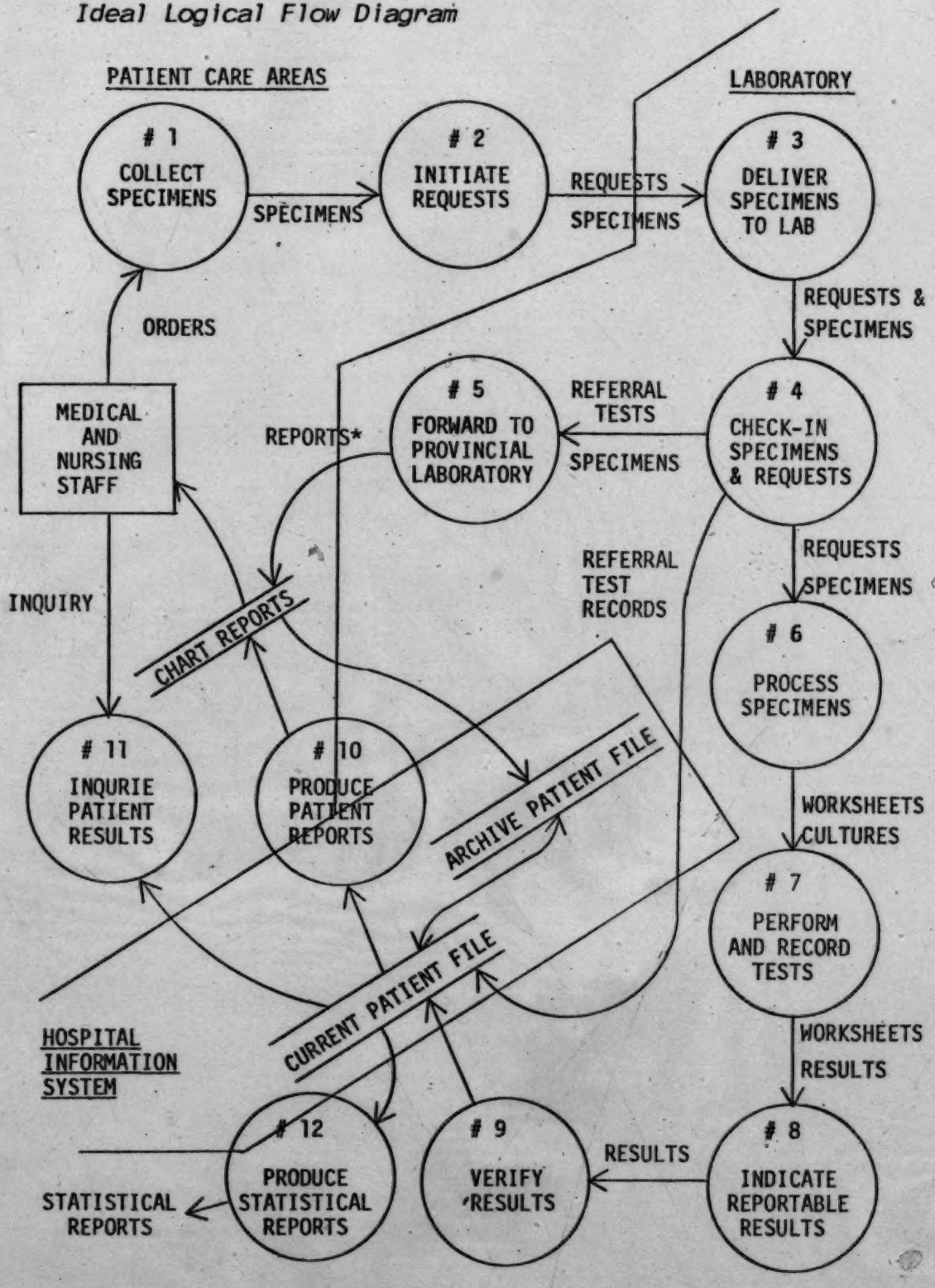
The following computer equipment would be needed in order to support the proposed changes:

1. On nursing stations:
   a. one CRT per 18-bed unit.
   b. one printer per 54-bed station (optional).
2. In Microbiology Dept there should be sufficient numbers of the following:
   a. CRT's equipped with wand readers.
   b. Bar-code label printers.
   c. Medium speed printers.

Diagram 1. An ideal logical flow diagram for microbiology specimens and reports in the Dept. of Microbiology at U. of A. Hospital in Edmonton, Alberta.

Proposed Model For Microbiology Specimens & Reports

Ideal Logical Flow Diagram



*REPORTS SHOULD EVENTUALLY BE STORED IN THE CURRENT PATIENT FILE

Details of Processes

#01 COLLECT SPECIMENS:

1. Information on collection procedures and appropriate types of specimen containers can be obtained from:
   a. Specimen collection and processing manual on nursing stations.
   b. Consultation with microbiology laboratory staff.
2. Specimens are collected by nursing or paramedical staff, except for surgical and biopsy specimens which are collected by doctors.
3. Once the specimen is collected, an adhesive label which contains the patient data and specimen type should be affixed to the specimen.

#02 INITIATE REQUESTS:

1. The following information has to be provided with the request:
   a. Specimen type/source.
   b. Test name(s).
   c. Request date/time.
   d. Collection date/time.
   e. If detection of a particular pathogen is desired, indicate the pathogen's name.
   f. Admitting and subsequent diagnoses

(optional).

g. Antibiotics in use (optional).

2. Some tests may only be requested on certain types of specimens. They are listed as follows:

a. BLOOD CULTURE on bloods, bone marrow.

b. GC SCREEN on genital specimens, throat, mouth & lip swabs.

c. STREPT SCREEN on throat specimens.

d. PID SCREEN on genital specimens.

e. COLONY COUNT/C & S on urines and fluids.

f. ANTIBIOTIC ASSAYS on bloods, CSFs, fluids.

g. TRICHOMONAS EXAM on genital specimens.

h. OVA & PARASITES on stool, urine, cecal aspirate, protoscopic specimens.

i. GIARDIA EXAM on stools, cecal aspirates.

j. PIN WORM on scotch tapes, stools.

k. GENITAL SCREEN on genital specimens.

l. PERTUSSIS SCREEN on augers, nasopharyngeal & throat swabs.

m. URINARY AB-COATED BACT on urines.

n. TOXIN ASSAY for Clostridium difficile on stools. History and antibiotics in use required.

o. MYCOPLASMA & CHLAMYDIAL CULTURES on urine, respiratory tract specimens and genital specimens, bloods, fluids.

p. FUNGAL & VIRAL SEROLOGY on bloods and

fluids.

q. All other serology tests on bloods and fluids.

r. Only ONE stool allowed for OVA & PARASITES daily.

s. Only ONE sputum and urine allowed every 48 hrs.

3. CIE on CSFs outside of 8 to 4 p.m., Monday to Friday, need consultation and authorization from the Microbiologist.

4. All tissues and biopsies would automatically be requested for FUNGAL CULTURE and TB CULTURE and sent to Prov Lab.

5. ANAEROBIC CULTURES are not allowed on the following specimens except by authorization from the Microbiologist:

a. Urines.

b. Throat and nose swabs.

c. Sputums.

d. Bronchial washings.

e. Cervical/vaginal swabs.

f. Feces.

g. Burn sites.

h. Tracheal swabs.

6. The following tests are not performed on the evening shift after 1700 hrs:

a. FUNGAL CULTURES.

b. MYCOPLASMA & CHLAMYDIAL CULTURES.

c. OVA & PARASITES.

d. All serology tests.

e. TB CULTURE.

f. VIRAL CULTURE.

7. ANAEROBIC CULTURES are requested separately from the ROUT C & S.

8. Referral tests are requested similarly as the other tests.

#03 DELIVER SPECIMENS TO LABORATORY:

1. STAT specimens such as CSFs and blood cultures are brought to the laboratory as soon as they are collected.

2. Routine specimens are put into plastic bags and sent to the lab via the telelift system OR by portering service.

3. After 2200 hrs blood cultures and CSFs are to be left in the blood culture incubator in lab.

#04 CHECK-IN SPECIMENS AND REQUESTS:

1. Each request is checked against the requesting guidelines provided in #02. The technologist may:

a. approve the request, OR

b. phone nursing station for clarification if request information is not clear, then aprove the request.

2. If a similar specimen has already been received by the lab within the specified time period, the new request will be rejected.
   a. the technologist phones station to inform the rejection and asks for further instructions:
      1) If the doctor still wishes the specimen to be processed, proceed with processing the specimen and indicate 'duplicate specimen' on report.
      2) If request is not required it can be canceled.
3. For unlabeled OR mislabeled specimens:
   a. If specimen is unlabeled OR names from specimen label and request don't match, lab personnel must phone station to request someone handling specimens to return to lab and identify the specimen with the appropriate label.
   b. Failing that request, the lab staff will have to plant the specimen and indicate on report 'SPECIMEN UNLABELED WHEN RECEIVED' or 'NAMES ON SPECIMEN AND REQUEST DO NOT CORRESPOND' and date/time the nursing station was notified.
   c. With inappropriate specimen or invalid request, lab staff should phone nursing

staff for correction. Specimen may only be discarded with consent from requesting doctor or nursing staff.

d. If insufficient specimen, phone nursing staff on station for instruction. Discard specimen only with consent from requesting doctor or nursing staff.

4. Issue worksheet for each request. Identify each worksheet by the patient and request data, and the *accession number*.
5. If referral tests, record patient and request data and accession number on the appropriate *Prov Lab requisitions*.

#05 FORWARD TO PROVINCIAL LABORATORY:

1. Specimens for referral tests are sent to the Prov Lab via the telelift system or portering service.
2. Each specimen has to be accompanied by the appropriate Prov Lab requisition.
3. Records should be kept on all referral tests processed by the laboratory.

#06 PROCESS SPECIMENS:

1. Specimens are cultured according to the laboratory procedure manual.
2. Each plate is labeled with the accession number.
3. After inoculation, the plates are incubated

according to *sections*.

4. After incubation the plates are separated and forwarded to the appropriate sections.

#07 PERFORM TESTS AND RECORD RESULTS:

1. Tests are carried out in accordance with the procedure manual.
2. All observations and test results are recorded on the worksheets.
3. All isolates are numbered in ascending order with the most predominant ones first, e.g. 1, 2, 3, 4, etc.
4. Organisms submitted for sensitivities should be clearly labeled with the organism numbers. Specifically:
   a. When sensitivity results are ready to be recorded, the appropriate worksheets are collected from each section, and delivered to the Antibiotics section.
   b. Sensitivity results are then recorded under the appropriate antibiotic columns beside the corresponding organism number. All sensitivity results from the *sens panel* are recorded.
   c. After recording the sens results, the worksheets are returned to the respective sections.
5. Anaerobic culture results are recorded on the

anaerobic worksheet. If a patient has both an ROUT C & S and ANAEROBIC CULTURE requested on the same specimen, then the ROUT C & S results should be made available to the Anaerobic section for comparison.

6. On certain cultures, the technologist may wish to initiate additional referral tests. These referral tests are to be treated as separate requests on that specimen.
7. Gram smear, growth comments are recorded as required.
8. Updating of organism is allowed if it is within the same genus, or if it is from the species level to subspecies level, etc.

#08 INDICATE REPORTABLE RESULTS:

1. Organism names to be reported are indicated on the worksheet. Each one is to be clearly numbered.
2. Routine *reportable sens results* are indicated for the respective organisms.
3. Sensitivity results not usually reported can be reported upon special requests and they are also indicated on the worksheet.

#09 VERIFY RESULTS:

1. Results are verified by senior techs only.
2. When all results are available and verified the

test is considered finalized. Once finalized results cannot be altered.

3. On cultures where additional referral tests are initiated by the techs, the requests will not be considered finalized until referral test results are returned and verified.
4. Sens results for the particular organisms are checked to ensure that the results are acceptable. Certain results are considered *unlikely sens patterns* and these would require verification from senior techs.
5. Once results are verified they can be available to doctors.

#10 PRODUCE PATIENT REPORTS:

1. A daily report is issued on any test that contains new result information.
2. Cumulative reports are issued periodically to certain stations and upon request. The reports contain all the tests requested and all the results available within the specified time period. Any tests requested prior to the specified period but which are still outstanding will also appear on the cumulative report.
3. Reports can be delivered to stations via the telelift system.
4. For patients that have been discharged, the reports will automatically be delivered to the

attending doctors and Medical Records Dept.

5. If *infectious disease patient*, i.e. the patient is under the care or consultation by infectious disease consultant, a copy of each report will be issued to the consultant.

#11 INQUIRE PATIENT RESULTS:

All verified and finalized results are readily available to the doctors upon inquiry.

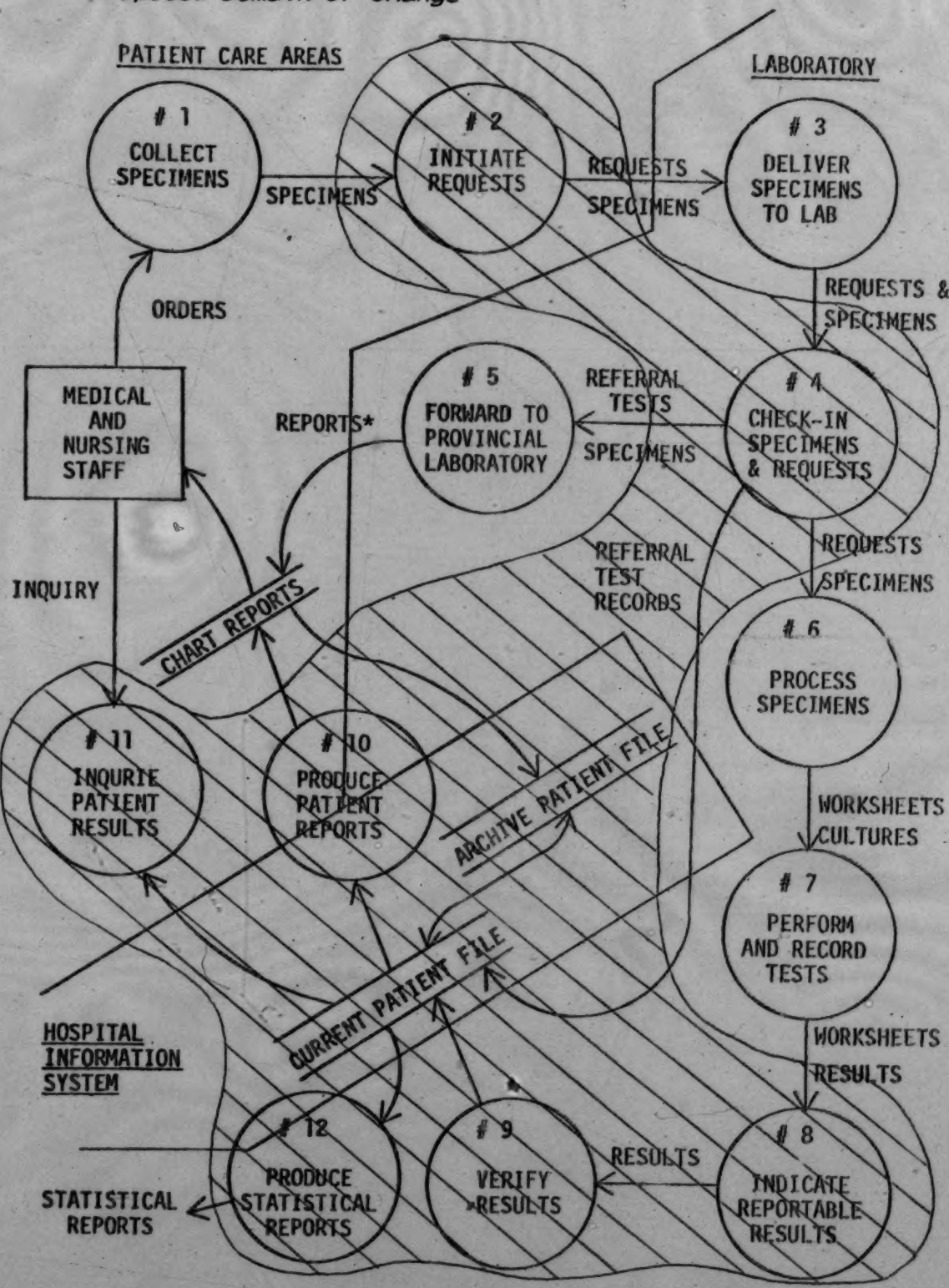
#12 GENERATE STATISTICAL REPORTS:

Various statistical reports are produced periodically for the laboratory administrative staff and infection control staff. These include:

1. Workload statistics report.
2. Specimen tally report.
3. Positive culture summary list.
4. Infection summary report.
5. Antibiotic susceptibility profile report.
6. Organism clustering report.

Diagram 2. The ideal logical flow diagram for microbiology specimens and reports with the proposed domain of change outlined in shaded areas.

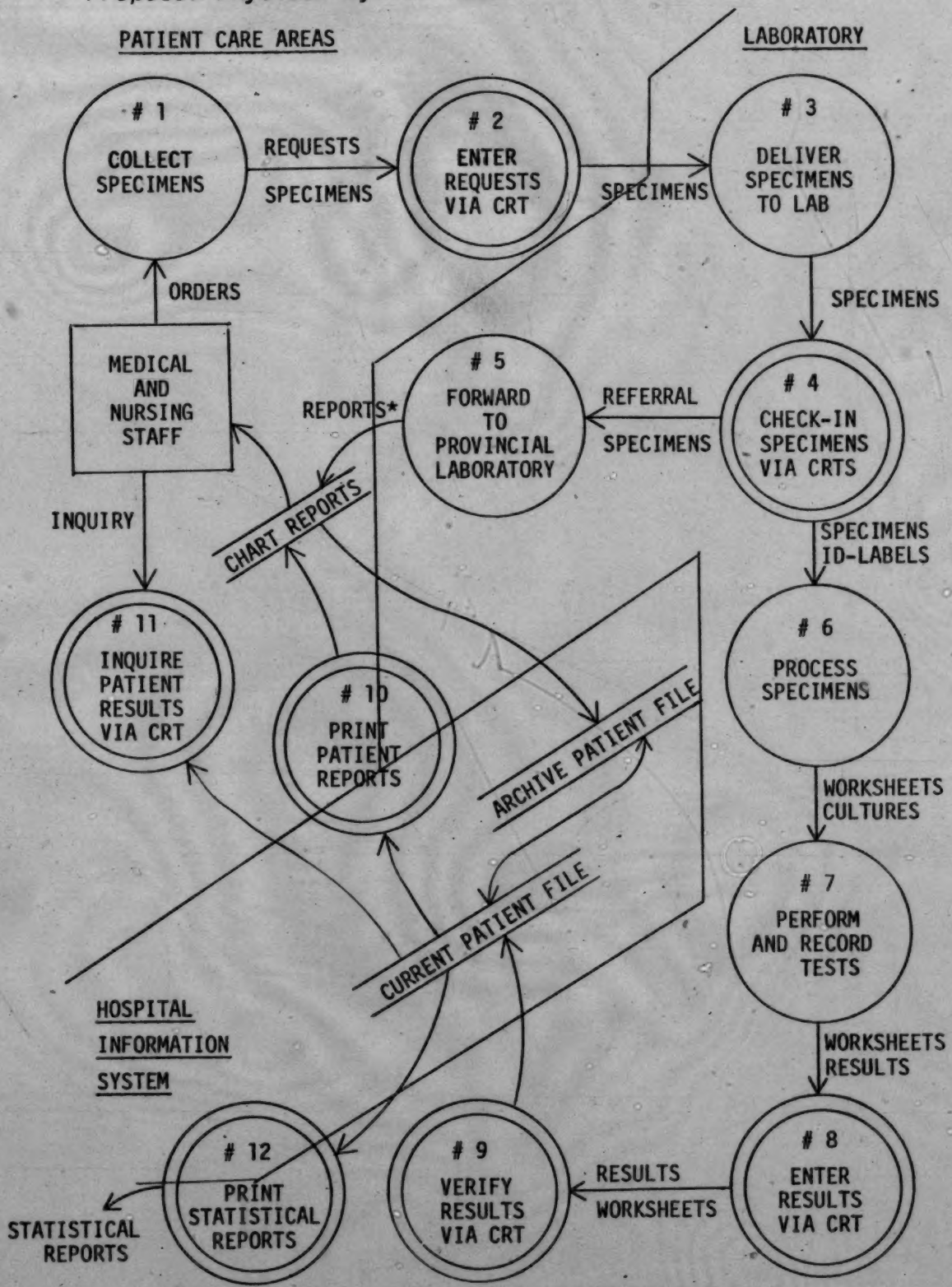
Proposed Domain Of Change



*REPORTS SHOULD EVENTUALLY BE STORED IN THE CURRENT PATIENT FILE

Diagram 3. A diagram of the proposed physical system model for flow of microbiology specimens and reports in the Microbiology Dept. at the University Hospital.

Proposed Physical System Model



*RESULTS SHOULD EVENTUALLY BE STORED IN THE CURRENT PATIENT FILE.

Details of Processes

Please note that only the man-machine interfaces, denoted by the double-ring bubbles, are described below:

#02 ENTER REQUESTS VIA CRT:

1. Initiate the test request routine by the appropriate command via the CRT.
2. Enter the patient ID. The relevant patient information will be displayed on screen for review.
3. Enter the appropriate code for Microbiology Dept. The specimen menu will be displayed immediately for selection.
4. Select the specimen type from the specimen menu displayed. Additional specimen description can be entered as free-text.
5. If the desired specimen type is not in the menu, one can enter the description by free-text.
6. Once the specimen type is entered, the appropriate test menu will be displayed for selection. More than one test may be requested for the specimen.
7. In addition one may select the pathogen(s) of interest from the pathogen menu.
8. If only the pathogen of interest is known, one can bypass the test and select from the pathogen menu. The computer will automatically order the

appropriate test that has been pre-defined for each pathogen on the menu.

9. For abscess/drain, wound, surgical wound, and burn specimens, if ROUT C & S is requested, the detailed site description is mandatory and will have to be provided.
10. Once the selection is complete, the request data will be displayed for review.
11. Record the accession number displayed onto the *specimen label* on the container.
12. If one is familiar with the specimen and test codes, he/she can bypass the menus and enter the codes directly.
13. Enter collection time if it is available.

#04 CHECK-IN SPECIMENS VIA CRT:

1. Initiate the check-in routine.
2. Enter the accession number that is written on the specimen container. If the number is not available, enter either the patient ID or name.
3. If accession number is entered, all requests under that number will be displayed. These will usually be the tests requested on the particular specimen.
4. If patient name or ID is entered, all requests on the patient will be displayed.
5. Requests are checked to acknowledge the receipt of the specimen. The tech may:

a. approve the requests, OR

b. make the necessary changes, then okay the requests. Changes may include:

   1) Change collection time and/or test procedure name.

   2) Add additional specimen description or comment.

   3) For specimens that are described only by free-text, if ROUT C & S is requested, the actual test procedure will be selected at this time. This may be done by entering the appropriate test procedure code.

   4) If additional media are required, they can be read-in via the wand reader from a list of media labeled with the appropriate bar-codes.

c. Reject invalid requests by canceling the test after consultation with the nursing stations.

6. Once checked-in, the *status* of the test will be changed from 'PENDING' to 'WORKPOOL'.

7. After a specimen is checked-in a set of *ID-labels* will be automatically generated. They are used to label the worksheet and the media.

#08 ENTER RESULTS VIA CRT:

1. Initiate the result entry routine.
2. Scan the ID label on the worksheet with wand reader to retrieve the appropriate patient record for display on CRT.
3. The appropriate menu will be displayed according to the specimen type.
4. Results can be entered via the keyboard at the appropriate brackets displayed on the screen and via function keys.
5. Updating of organisms can be done simply by typing over the same area for the organism with the more specific identification information.
6. Depending on the organism ID entered, the corresponding sensitivity panel will be displayed on the screen. One can then enter the appropriate sens results.
7. Sens results not usually reported can be reported by entering a command code directly beside the sens result.

#09 VERFIY RESULTS VIA CRT:

1. Any results to be sent out as interim or final reports can be viewed through a verify result routine on the CRT. Alternately, optional hard-copies can be obtained for verification.
2. Results displayed are compared against the

worksheets. Any discrepancies or errors can be corrected immediately via the CRT and then verified, OR verification is denied and corrections can be made at a later time.

3. Sens results are checked for unlikely patterns and any such patterns will require verification from the senior staff.

#10 PRINT PATIENT REPORTS:

1. Both the daily and cumulative reports can be printed either directly on the nursing stations or in the laboratory.
2. If patient has been discharged, the reports will be automatically directed to the attending doctors and the Medical Records Dept.
3. A copy of each report is sent to the appropriate infectious disease consultant if the patient is under his/her consultation.

#11 INQUIRE PATIENT RESULTS VIA CRT:

1. Any verified and finalized results can be accessed via CRT directly on the nursing stations. Optional hard-copies can be obtained from the printer located on the station upon request.
2. Only authorized personnel may inquire and view the test results.

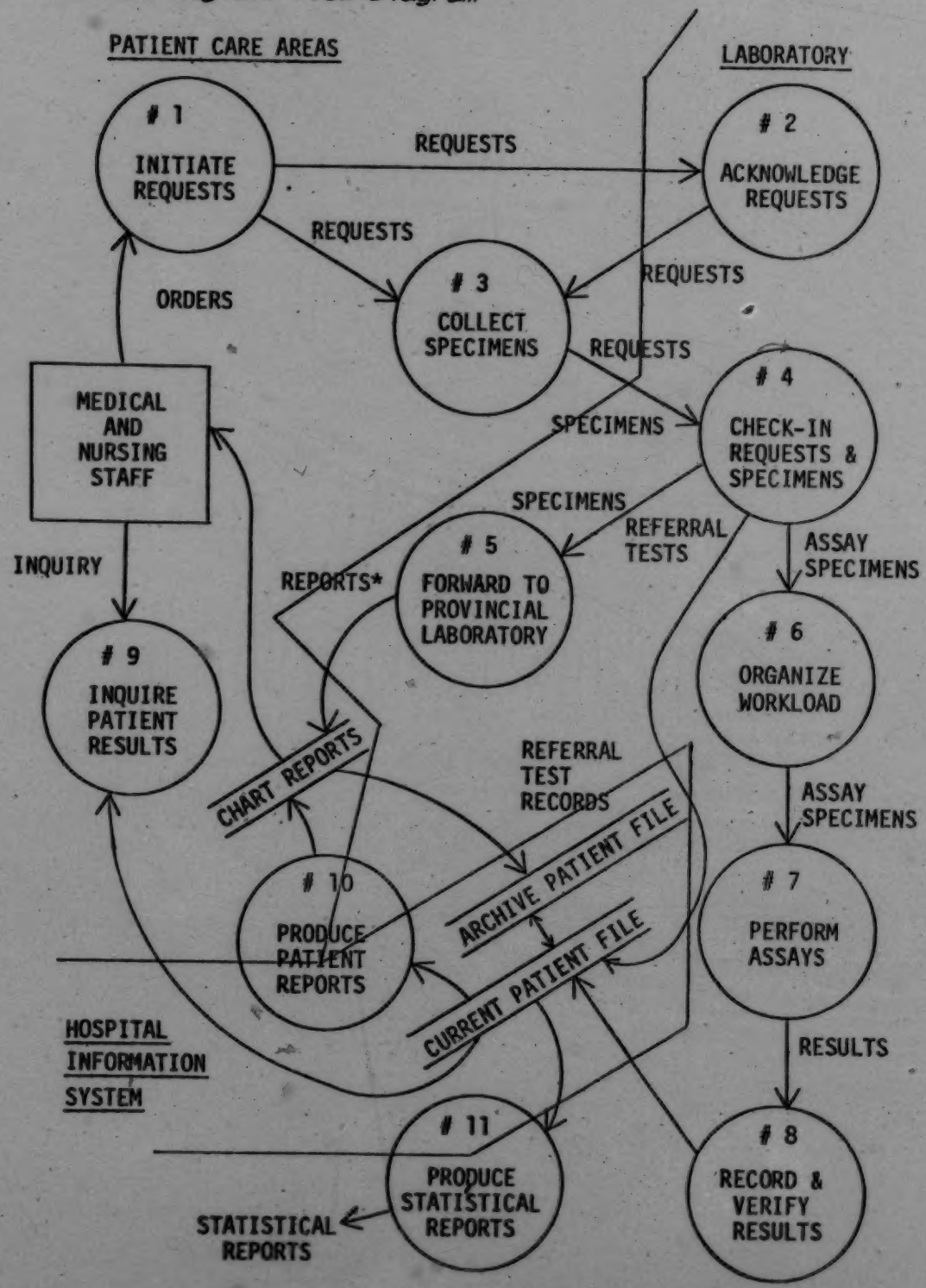
#12 PRINT STATISTICAL REPORTS:

1. Various statistical reports are printed in the laboratory periodically and as required.
2. Alternately, these reports may be viewed directly on the CRT in lab.

Diagram 4. An ideal logical flow diagram for serological, antibiotic assay specimens and reports for the Microbiology Dept. at the University Hospital.

Proposed Model For Serological, Antibiotic Assay Specimens & Reports

Ideal Logical Flow Diagram



*REPORTS SHOULD EVENTUALLY BE STORED IN THE CURRENT PATIENT FILE.

Details of Processes

#01 INITIATE REQUESTS:

1. The type of specimen has to be indicated.
2. For all miscellaneous serology and viral serology tests, the specific test name(s), and/or suspected agent/diagnosis, have to be indicated.
3. With Antibiotic Assay tests, the following information are required:
   a. For Antibiotic Levels -
      1) Antibiotic to be tested.
      2) Date/time of last dose.
      3) Date/time of next dose.
      4) Route of administration.
      5) Dosage and duration of infusion.
      6) Indicate pre/post sample.
      7) Other antibiotics in use.
   b. For Synergistic Studies -
      1) Organism name.
      2) Accession number.
      3) Antibiotic names (2 names).
   c. For Serumcidal & static levels -
      1) Blood culture accession number.
      2) Organism name.
      3) Antibiotic name.
      4) Indicate pre/post sample.

5) Date/time of last dose of antibiotic.

d. MIC/MBC levels -

1) Organism name.

2) Antibiotic name(s).

4. Chloramphenicol levels have to be sent to lab by 9:00 a.m. each day.

5. For levels other than aminoglycosides and chloramphenicol, 24 hour advance notice is required.

6. The *ideal collection date/time* is derived from the date/time of the antibiotic last given or to be given.

#02 ACKNOWLEDGE REQUESTS:

1. The lab staff check to ensure that all information is present for the request.

a. If some information is incomplete, phone station to clarify.

b. If invalid request, consult station. Cancel request only with permission from authorized personnel.

2. All valid requests are forwarded to the blood collection team in Dept. of Lab Medicine who would in turn go to collect the blood specimens.

#03 COLLECT SPECIMENS:

1. Phlebotomist collect blood specimens on stations.

a. If successful, record actual collection time and bring down specimens.

b. If unable to get specimen, station is notified:

1) For antibiotic assays, leave request with station to have blood collected or test canceled by doctors.

2) For serological tests, fill out 'MISSED-COLLECTION' form on station. Specimen is then collected by doctor OR by another phlebotomist sent up at later time.

#04 CHECK-IN REQUESTS & SPECIMENS:

1. Specimens with the appropriate requests are checked-in at the laboratory specimen receiving section. Each specimen is checked to ensure:
   a. The correct patient and specimen.
   b. Sufficient sample.
   c. For antibiotic assays -
      1) 1 ml required for aminoglycosides.
      2) 5 mls required for all other assays.
2. Referral tests for Prov Lab are logged for records.
3. Antibiotic assay specimens are then forwarded to Antibiotics section.

#05 FORWARD TO PROVINCIAL LABORATORY:

1. Serological tests are sent to Prov Lab. Each specimen has to be accompanied with the appropriate Prov Lab requisitions.
2. Results from Prov Lab are forwarded directly to the stations.

#06 ORGANIZE WORKLOAD:

Record accession number for each specimen in result entry log under the tests to be done that day.

#07 PERFORM ASSAYS:

Assays are performed according to the established antibiotic assay protocols.

#08 RECORD & VERIFY RESULTS:

1. Results are recorded according to the accession number listed in the log.
2. Results within the acceptable range can then be finalized. Those outside of the recommended range will be reviewed by senior tech before finalization.

#09 INQUIRE PATIENT RESULTS:

1. All finalized results are phoned to nursing stations. Initials from person receiving the results over the phone are required for confirmation purposes.
2. Doctors may also phone the Antibiotics section

to inquire any results.

#10 PRODUCE PATIENT REPORTS:

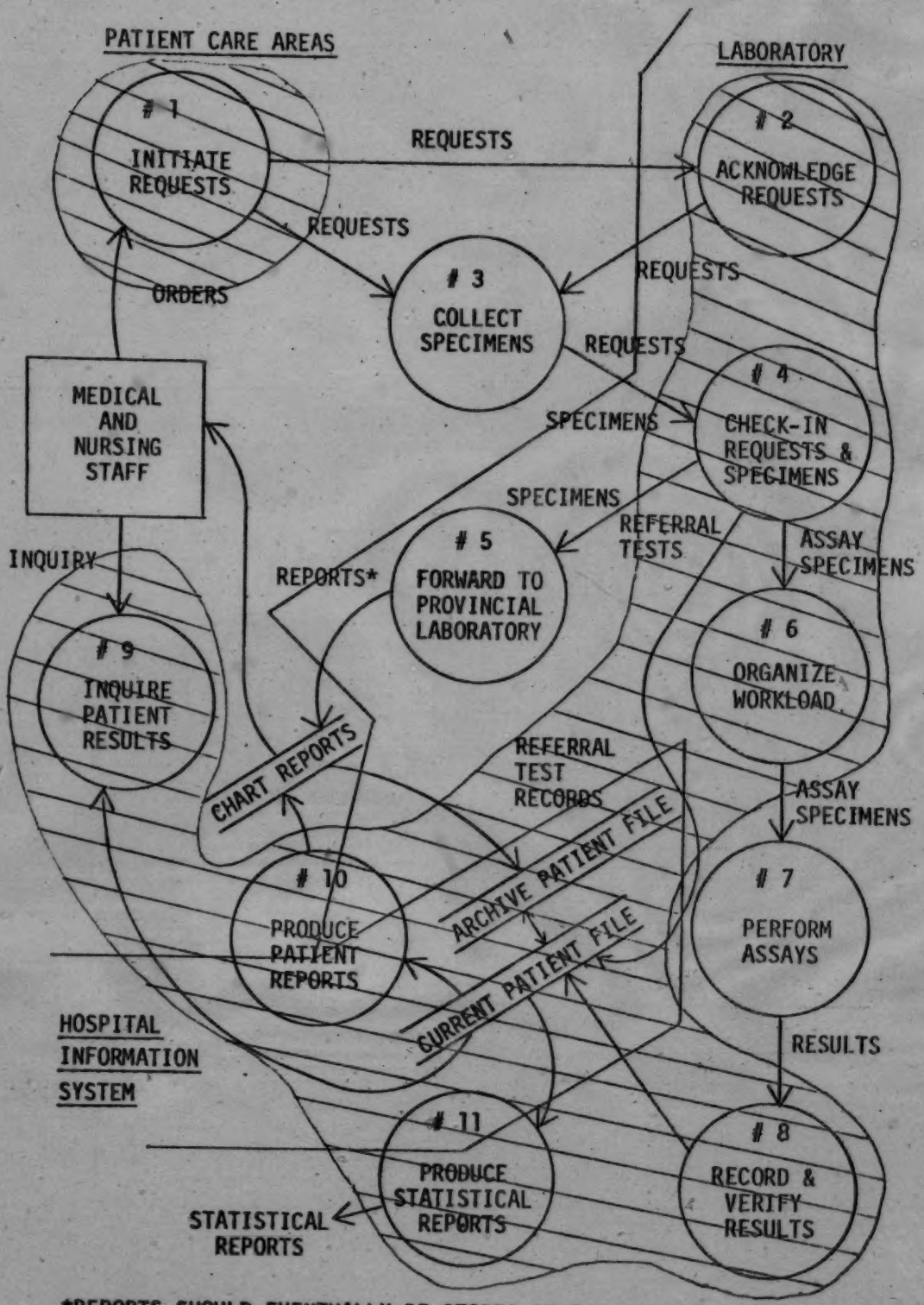
1. Daily reports are produced and distributed to stations on finalized results. Pending requests are also included.
2. Information that are included in the report are as follows:
   a. Patient data.
   b. Request data, including test name, dose, time, route, etc.
   c. Results.
3. Cumulative reports are available for certain stations and upon requests. These reports are usually cumulative for up to 7 days and are in chronological order with the most recent assays listed at the beginning.
4. If patient has been discharged, all reports will be sent directly to the doctors offices and Medical Records.

#11 PRODUCE STATISTICAL REPORTS.

1. Periodically, workload statistics are produced giving the total number of tests performed during a specified period and the total work units.

Diagram 5. The ideal logical flow diagram for serological, antibiotic assay specimens and reports with the proposed domain of change outlined in shaded areas.

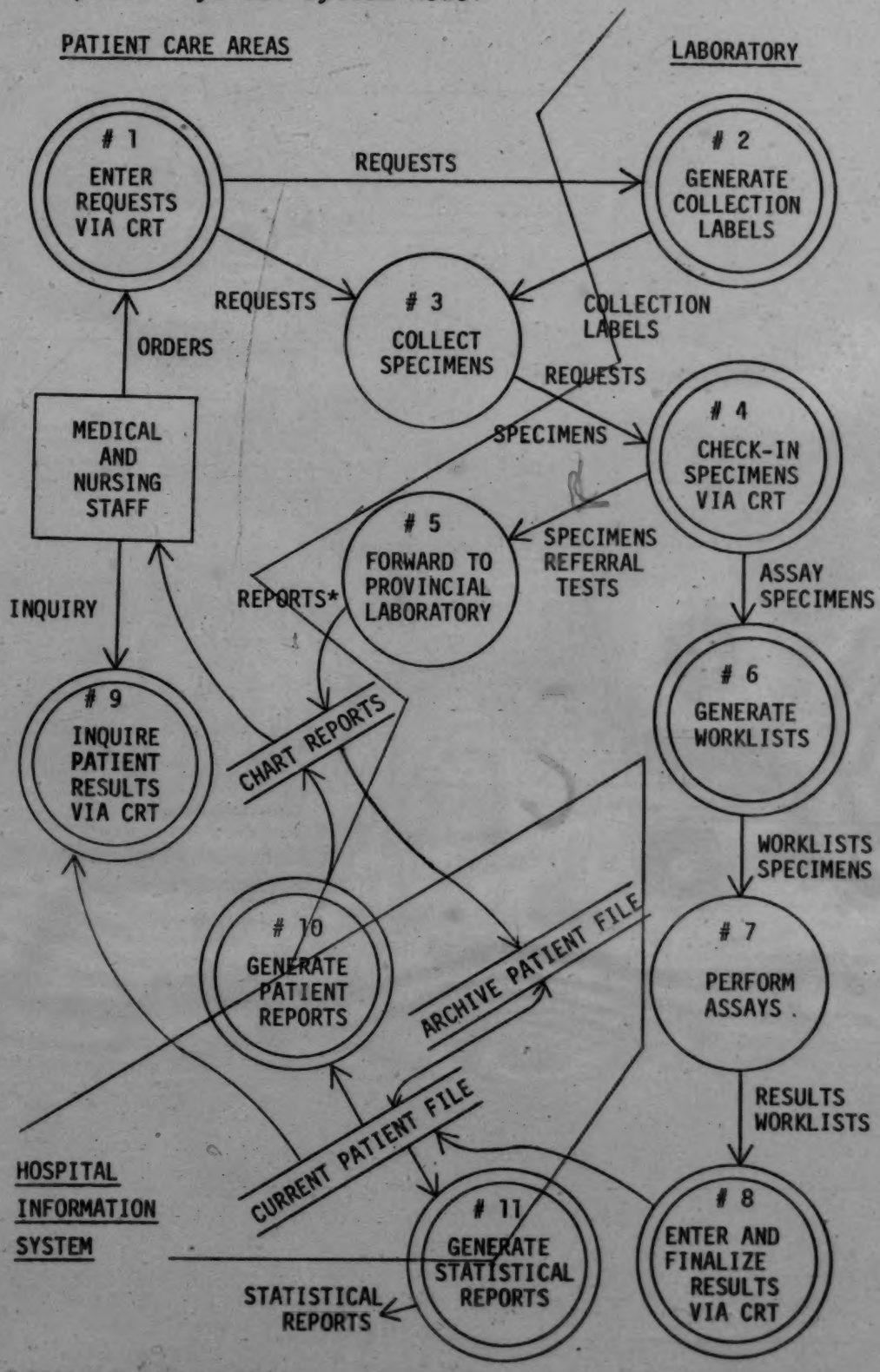
Proposed Domain Of Change



*REPORTS SHOULD EVENTUALLY BE STORED IN THE CURRENT PATIENT FILE.

Diagram 6. The proposed physical system model for flow of serological, antibiotic assay specimens in the Microbiology Dept. at the University Hospital.

Proposed Physical System Model



*RESULTS SHOULD EVENTUALLY BE STORED IN THE CURRENT PATIENT FILE

Details of Processes

#01 ENTER REQUESTS VIA CRT:

1. Nursing staff or clerks enter requests via CRT on stations by initiating a test requesting routine.
2. Relevant information has to be provided before the request can be accepted. For example,
   a. The specimen type and test name(s) have to be indicated.
   b. For antibiotic assays, all information, such as antibiotic name, last dose, route, etc., must be entered.
      1) From the time of last/next dose and pre/post sample indication entered, the ideal collection time for the specimen is automatically derived and indicated on the screen.
3. For assays other than aminoglycosides and chloramphenicol (these are the ones requiring 24 hour notice):
   a. Before 1600 hrs:
      1) Request the assay by entering all the required information.
      2) From the last/next dose the computer will automatically calculate the ideal collection time.

3) After requesting, the nursing staff should phone the Antibiotics section to confirm the request.

4) The lab staff will work out the ideal collection time from the information provided by the nurse over the phone. If it is different from the ideal collection time that is in the computer, the time in the computer will be changed to the one derived by the lab staff.

b. After 1600 hrs:

1) All assay requests are denied.

2) Nursing staff is advised to phone the Antibiotics section the following morning for consultation.

#02 GENERATE COLLECTION LABELS:

1. As soon as there is an assay or serology test requested, a set of *collection labels* will be printed in the Specimen processing section in the lab. All patient and request data are printed on the labels.
2. Labels for all antibiotic assays, except for aminoglycosides, will be generated just prior to the actual ideal collection time.

#04 CHECK-IN SPECIMENS VIA CRT:

1. Specimens are returned to the specimen receiving area with labels. At that point, the collection is verified via the check-in routine which will change the status of the test from 'PENDING' to 'COLLECTED'.
2. During the check-in process, the tech does the following:
   a. Verifies the collection, OR
   b. Makes the necessary changes on the request information displayed on screen, such as collection time, etc., and then verifies the collection.
   c. Cancels the test due to invalid specimen or insufficient sample. Must have permission from authorized personnel from nursing station.
3. If specimen is brought down to lab before the test is requested, the tech in the receiving area can initiate the test request and check-in the specimen at the same time.
4. After check-in of serological tests, additional sets of ID-labels will be printed. These labels are used to label the Prov Lab requisitions.
5. Antibiotic assay specimens are forwarded to Antibiotics section. Upon receipt of the specimens the tech in the Antibiotics section

verifies the receipt via the check-in routine again which will change the status of the test from 'COLLECTED' to 'WORKPOOL'.

6. Optional hard-copies can be requested from the check-in routine on tests that are still pending or collected.

#06 GENERATE WORKLISTS:

1. Prior to performing the assays, worklists can be requested via a print routine. This will list all specimens received by the Antibiotics section for a particular test up to that point. Each list is identified by a unique *list number*. The status of the test is now in 'WORKLIST'.
2. Once a request has been printed, it will not appear on subsequent worklists for that test, except
   a. If the test needs to be repeated, the status can be changed back to 'WORKPOOL'.
   b. The list can be reprinted.
3. All results are recorded on the worklists by the appropriate accession numbers.

#08 ENTER & VERIFY RESULTS VIA CRT:

The following only refers to antibiotic assays. Results from Prov Lab are forwarded directly to stations.

1. When results are ready to be entered, a result

entry routine can be initiated. One can enter the list number on the worklist. The requests that are on the worklist will be displayed for result entry.

2. All request data are displayed on the result entry screen. Results can be entered at the designated areas.
3. After the results are entered, they can be finalized immediately.

#09 INQUIRE PATIENT RESULTS VIA CRT:

1. Any finalized antibiotic assay results are available via the patient inquiry routine which can be initiated directly via the terminals on stations.
2. Any serology tests requested can also be displayed on the screen to indicate their status, which would either be 'PENDING', 'COLLECTED', or 'PROV LAB'.

#10 GENERATE PATIENT REPORTS:

1. As soon as a test is finalized, a daily report is automatically printed at the station.
2. Cumulative reports are also printed for selected stations and upon requests in the lab and distributed to the stations.

#11 GENERATE STATISTICAL REPORTS:

The number of assays performed and serology tests processed and the corresponding work units are tallied and printed along with the other workload statistics periodically.

Data Dictionary

ACCESSION NUMBER

The accession number should have two components:

1. A 'two-letter code' that indicates the section that the specimen is to be processed at. This code is determined by the type of specimen submitted. The following are the codes used at present:
   a. MU - miscellaneous specimens.
   b. U - cystoscopy urine specimens.
   c. C - colony count urine specimens. pt>DU - nose and throat specimens.
   d. GU - vaginal, cervical, and male genital specimens.
   e. W - W.W.Cross specimens.
   f. BC - blood cultures.
   g. EU - stool specimens.
   h. A - anaerobic cultures.
2. A six-digit number that begins from one at the beginning of each year.

COLLECTION LABELS

These are labels that are printed from the label printer in the Specimen processing section when there is an antibiotic assay requested. A proposed layout for the label is shown in figure 39.

Name Location ID Age & Sex Test Name Pre/Post Last Dose Other Abs ACC # Col Time Date	Name Location ID Age Sex Test Name Acsn nr. Name Location ID Age Sex Test Name Acsn nr.

Figure 39. A proposed layout of the collection label is shown here.

IDEAL COLLECTION DATE/TIME

These refer to the antibiotic assay specimens:

1. For IV -
   a. Pre - 1/2 hour before infusion.
   b. Post - 1 hour after infusion is complete.
2. For IM - 1 1/2 hours after the injection.

ID LABELS

These labels should contain at least the following:

1. Patient data.
2. Request data.
3. Received date/time.
4. Types of media for the particular tests.

INFECTIOUS DISEASE PATIENTS

These are patients that have been referred to the Infectious Disease Service for consultation. After consultation, if there are any new test results reported they will be automatically printed along with the daily reports under the consultant's name and forwarded to the consultant.

LIST NUMBER

Each list that is printed is identified by a unique number that is generated along with the list. If reprint is desired, the number is used as the reference.

PROVINCIAL LABORATORY REQUISITIONS

The Provincial Laboratory of Public Health has its own requisitions for each type of test procedure. They are as follows:

1. Routine Cult & Sens requisitions.
2. Mycology requisitions.
3. TB requisitions.
4. Virology culture and serology requisitions.
5. Serology requistions.

REPORTABLE SENS RESULTS

1. For Staph - pen, ox, eryth, ceph, gent. If eyes + chlora.
2. For Strep, Aerococci - pen, eryth, ceph, amp, gent.
3. For Diphtheroids - pen, ox, eryth, ceph, gent.
4. Non-urine specimens:

a. All coliforms except Pseudomonas sp. - ceph, kana, tetra, amp, coly, chlora, gent.

b. For indole +ve Proteus - above + tobra, tic.

c. Pseudo sp of fluorescens gp - kana, coly, gent, tob, tic.

d. Pseudo non-aeruginosa - above + tetra, chlora.

e. For Salmonella - ceph, kana, tetra, amp, coly, chlora, sulfa, SxT, trim.

f. Pasteurella, Moraxella - ceph, kana, tetra, amp, coly, chlora, gent, pen.

5. Blood and CSF specimens:

a. Same as non-urines and + sulfa, SxT, trim for coliforms.

b. Pseudomonas of fluorscens gp - kana, coly, gent, tobra, tic, sulfa, SxT, trim.

6. Urine specimens:

a. Pseudomonas of fluorescens gp - kana, coly, gent, tobra, tic, sulfa.

b. Pseudomonas non-aeruginosa - kana, coly, gent, tobra, tic, tetra, sulfa.

c. All other coliforms - ceph, kana, trtra, amp, gent, fd, Na, sulfa, SxT, trim.

d. Proteus indole +ve - above + tobra, tic.

7. For Hemophilus - cefamandole, tetra, chlora, eryth, gent, SxT, amp.

8. Neisseriae meningitidis - pen, chlora, tetra, gent, sulfa.

9. Neisseriae gonorrheae - pen.
10. All anaerobes - pen, clin, tetra, chlora, cefox, tic.
11. Eikenella - pen, chlora, amp.
12. Hemolytic Strept & Pneumococci - pen, eryth, ceph, tetra.
13. Strept sp -
    a. If aerobic - pen, ox, eryth, ceph, gent.
    b. If anaerobic - pen, tetra, clin, chlora, cefox, tic.

SECTIONS

The Microbiology Dept is separated into:

1. Specimen processing section or mail room.
2. Miscellaneous University section.
3. Antibiotics section.
4. Anaerobes section.
5. Special non-routine test procedures section.
6. Wash up and media section.
7. Chlamydia & Mycoplasma section.

SENSITIVITY PANELS

1. Gram positive organisms: Penicillin. Methicillin. Erythromycin. Cephalothin. Ampicillin. Gentamicin. Chloramphenicol.
2. Gram negative organisms (non-urine origin): Cephalothin. Kanamycin. Tetracycline. Ampicillin. Colistin. Chloramphenicol. Gentamicin. Tobramycin.

Ticarcillin.

3. Gram negative organisms (urine origin):Nitrofurantoin. NA. Sulfa. Septra. Trimeth. Penicillin. Methicillin. Erythromycin. Cephalothin. Ampicillin. Gentamicin.
4. Gram negative organisms (non-urine origin): Cephalothin. Kanamycin. Tetracycline. Ampicillin. Colymicin. Chloramphenicol. Gentamicin.Tobramycin. Ticarcillin.
5. Anaerobes: Penicillin. Clindamycin. Tetracycline. Chloramphenicol. Ticarcillin. Cefoxitin.
6. Strept pneumoniae & hemolytic Streptococci: Penicillin. Erythromycin. Cephalothin. Tetracycline.

SPECIMEN LABELS

1. Specimen labels should have space for the patient addressograph, the specimen/source and the collection time/date.
2. They should be adhesive labels that can be easily affixed firmly onto the specimen containers.

STATUS

The following are the statuses available within the system:

1. PENDING. This means that the test has not been received in the lab.
2. COLLECTED. For antibiotic assays and serological tests only. This means that the specimen has been

collected and received in the Specimen processing section.

3. WORKPOOL. This means that the test has been received in the lab.
4. WORKLIST. For antibiotic assays only. This means that the tests are being performed at the moment.
5. VERIFY. This means the test is being verified.
6. PRELIMINARY. This means the test has had a preliminary report sent already.
7. INTERIM. This means that the test has had two or more reports sent already.
8. FINAL. This means the test has been finalized.
9. PROV LAB. This means the specimen has been sent to Provincial Laboratory.

UNLIKELY SENS PATTERNS

1. For Staph aureus - resistant to pen and ox.
2. For Staph sp - resistant to ox and sensitive to pen.
3. Resistant to colistin but not one of Serratia, Proteus or Providencia.
4. Any organisms sens or resistant to all but any 2 antibiotics.

WORKSHEET

There should be two worksheets that are to be used in the lab. One is the anaerobic worksheet and the other is the routine worksheet.

Data Base Requirements

The following are the minimum amount of patient information that are required for the system:

1. Standard patient data.
   a. Patient name.
   b. Hospital identification number.
   c. Sex, birthdate.
   d. Alberta health care insurance number or blue cross number.
2. Case-specific data.
   a. Case number.
   b. Station location and room number.
   c. Attending physician.
   d. Consulting physicians.
   e. Admitting and other diagnoses.
3. Request data.
   a. Specimen type/source.
   b. Detailed specimen description (optional).
   c. Test name.
   d. Requested date/time.
   e. Collected date/time.
   f. Received date/time.
   g. Reported date/time.
   h. Requesting location.

Most microbiology results are to be pre-defined and stored in the system. These include the nomenclature, gram smear and comment results, antibiotic names, and specimen

types, etc. Where possible, the coding should conform to the SNOMED coding system.

Computer Procedure Requirements

1. A test request routine is required to accept all microbiology test requests. Menus are provided for selection of specimens and tests. Alternately, experienced users may bypass the menus and enter the respective codes directly.
2. A check-in routine is required to acknowledge receipt of all specimens. One should also be able to monitor specimens at all status via this routine.
3. A cancel routine is needed to cancel any invalid requests and tests that are no longer required.
4. One or more print routines will be needed for printing various lists and reports.
5. A patient inquiry routine is required to retrieve all verified and finalized microbiology results on a particular patient.
6. A result entry routine is required to accept all microbiology results. Results may be from the worklists or on certain accession numbers.
7. A verify routine is required for verification of all microbiology results.

Input/Output Requirements

The items in the following menus are the minimum amount of information required for test requesting and result entry in microbiology. Additional instructions should be included

where appropriate to assist users in proceeding with the routines.

Test Request Menus

In test requesting, the specimen menu is always displayed first. Depending on the choice selected, the computer will branch to the appropriate test menus for test selection. The pathogen menu always appears to the right of the test menu and both are displayed at the same time. These menus are shown in figure 40.

SPECIMEN MENU

Respiratory tract...

1 Auger suction
2 Bronchial washing
3 Nose swab
4 Sputum
5 Throat swab
6 Tracheal secretion

Fluids.....

7 Blood
8 CSF
9 Dialysis fld
10 Hyperalimentation
11 Joint-synovial fld
12 Pleural fluid

Urine-feces.....

13 Feces
14 Urine-M.S.
15 Urine-Catheter
16 Urine-Cystoscopy
17 Urine-Supra

Genital tract...

18 Cervix
19 Endocervix
20 Urethral
21 Vaginal

Tissues.....

22 Biopsy-tissue
23 Lung
24 Lymph
25 Bone chips

Tubing-Tips.....

26 Chest tube
27 ET tube-tip
28 Hemovac tube
29 IV tip

Swabs.....

30 Ear
31 Eye

Abscess, Drain...

32 Brain-head
33 Chest-shoulder
34 Genital
35 Abdominal
36 Rectal

37 Burn site*

38 Brain-head
39 Chest-shoulder
40 Genital
41 Abdominal

42 Tracheal site
43 Umbilical swab

Wound.....

44 Abdominal
45 Brain-head
46 Chest-shoulder

SELECTION ( ) DESCRIPTION ( )

Figure 40 a. The proposed specimen menu that is to be displayed on the CRT screen is shown here. To select a specimen simply type the corresponding number in the SELECTION bracket. Additional comments can be entered as free-text in the DESCRIPTION bracket.

MASTER TEST MENU

1 ROUT C & S	18 STREPT SCREEN	35 TORCH SCREEN
2 ANAEROBES	19 PERTUSSIS	36 WET MOUNT
3 BLOOD CULTURE	20 CIE	37 KOH
4 COLONY COUNT/C&S	21 TRICH EXAM	38 INDIA INK
5 MYCOPLASMA CULT	22 GRAM SMEAR	39 BCG STUDIES
6 CHLAMYDIA CULT	23 GIEMSA SMEAR	40 WORM ID
7 VIRAL CULTURE	24 URINE AB-COAT	41 BUG ID
8 FUNGAL CULTURE	25 ENVIRONMENTAL	42 SYPHILIS
9 TB CULT/SMEAR	26 TOXIN ASSAY	43 BRUCELLA
10 GENITAL SCREEN	27 ATYPICAL TB	44 PAUL BUNNEL
11 OVA & PARASITES	28 PID SCREEN	45 FUNGAL CULT
12 STERILITY TEST	29 DIRECT EM	46 TOXO-IFA
13 QUANTITATIVE CULT	30 GC SCREEN	47
14 STREPT SCREEN	31 VIRAL SEROLOGY	
15 PERTUSSIS	32 VIRAL SCREEN	
16 PID SCREEN	33 ANTIBIOTIC ASSAY	
17 ENVIRONMENT CULT	34 STREPT SEROLOGY	

Figure 40 b. The master microbiology test menu is shown here. The master test menu can be selected via the other test menus. In addition, the selection of certain test categories from this menu will prompt the display of more tests for further selections. These are displayed on the following pages.

ASSAY & SEROLOGY MASTER TEST MENU

Syphilis serology
1 RPR/Kahn
2 MHA-TP
3 TPI
Antibiotic assay
4 Antibiotic level
5 MIC/MBC level
6 Synergy study
7 Serumcidal level
Strept serology
8 ASOT
9 AntiDNase
10 Streptozyme
11 Streptodornase
12 Streptokinase
13 Antihyaluron
14 Brucella agglut
15 Viral screen

Fungal serology
16 Candidiasis
17 Cryptococcus
18 Histoplasma
19 Aspergillus
20 Mucor
21 Blastomyces
22 Coccidioides
23 Torulopsis
24 Sporothrix
25 Paracoccidioide
26 Farmer's lung
27 Unknown
28 Others*
29 Toxoplasma-IFA
30 TORCH screen

Viral serology
31 Adenovirus
32 Influenzae
33 Parainfluenza
34 CMV
35 Herpes simplex
36 Measles
37 Rubella
38 Variola
39 Rubeola
40 Epstein bar
41 Rota virus
42 Others*
43 Paul Bunnel

PATHOGENS MENU - PATHOGENS OF INTEREST

1 ACTINOMYCES
2 BRUCELLA
3 CAMPYLOBACTER
4 CANDIDA/YEASTS/MONILIA
5 CLOST DIFFICILE
6 DIPHTHERIA
7 GIARDIA/AMOEBAE
8 L-FORM BACTERIA
9 PATHOGENIC E. COLI
10 PSEUDOMONAS
11 SALMONELLA/SHIGELLA/YERSINIA
12 STAPH AUREUS
13 OTHERS*

*SPECIFY SPECIFIC PATHOGENS:

Figure 40 c, d. The assay & serology master test menu and the pathogens menu are shown here. Each of the above pathogens, when selected, will automatically select the appropriate test that has been pre-defined for that particular pathogen.

If any of the RESPIRATORY TRACT specimens is selected:

1 ROUT C & S
2 COLONY COUNT/C & S
3 CHLAMYDIA CULTURE
4 FUNGAL CULTURE
5 TB CULTURE/SMEAR
6 VIRAL CULTURE
7 PERTUSSIS SCREEN
8 STREPT SCREEN
9 QUANTITATIVE CULT (cystic fibrosis)
10 MASTER TEST MENU

If HYPERALIMENTATION FLUID is selected, the test is automatically requested as 'STERILITY TESTING'.

If any of FLUIDS is selected (except BLOOD and HYPER FLD), the test menu that will be displayed is as follows:

1 ROUT C & S
2 ANAEROBES
3 MYCOPLASMA CULTURE
4 CHLAMYDIA CULTURE
5 FUNGAL CULTURE
6 TB CULTURE/SMEAR
7 VIRAL CULTURE
8 CIE
9 DIRECT EM
10 ATYPICAL TB CULTURE
11 MASTER TEST MENU

Figure 40 e, f, g. Test menus for respiratory tract specimens and fluids are shown. To select the test of choice, simply enter the appropriate number.

If BLOOD is selected:

BLOOD FOR CULTURE .....

1 ROUT C & S/ANAEROBES
2 FUNGAL CULTURE
3 MASTER TEST MENU

BLOOD FOR SEROLOGY, ASSAYS .....

4 ASOT
5 SYPHILIS SEROLOGY (KAHN/RPR)
6 WIDAL
7 ANTIBIOTIC LEVELS
8 VIRAL SCREEN
9 RUBELLA
10 HEPATITIS
11 CYTOMEGALO VIRUS
12 FUNGAL SEROLOGY
13 ASSAYS/SEROLOGY MASTER TEST MENU

If FECES is selected:

1 ROUT C & S
2 OVA & PARASITES
3 CLOS DIFFICILE TOXIN ASSAY
4 VIRAL CULTURE
5 DIRECT EM
6 CULTURE - CLOST DIFFICILE
7 MASTER TEST MENU

Figure 40 h, i. Test menus for blood and feces specimens.

If URINE is selected:

1 COLONY COUNT/C & S
2 VIRAL CULTURE
3 TB CULTURE/SMEAR
4 ATYPICAL TB CULTURE
5 FUNGAL CULTURE
6 ANTIBODY-COATED BACTERIA
7 GRAM SMEAR
8 MASTER TEST MENU

If any one of the GENITAL TRACT specimens is selected:

1 ROUT C & S (incl. GC, Yeast, Trich)
2 ANAEROBES
3 MYCOPLASMA CULTURE
4 CHLAMYDIA CULTURE
5 FUNGAL CULTURE
6 G.C. SCREEN
7 P.I.D. SCREEN
8 GENITAL SCREEN
9 TRICH EXAM
10 GRAM SMEAR
11 MASTER TEST MENU

Figure 40 j, k. Test menus for urine and genital tract specimens are shown here.

If any of the BIOPSIES-TISSUES is selected:

1 ROUT C & S
2 ANAEROBES
3 MYCOPLASMA CULTURE
4 CHLAMYDIA CULTURE
5 TB CULTURE/SMEAR
6 VIRAL CULTURE
7 DIRECT EM
8 ATYPICAL TB CULTURE
9 FUNGAL CULTURE
10 GRAM SMEAR
11 MASTER TEST MENU

If any of the TUBING-TIPS is selected:

1 ROUT C & S
2 MASTER TEST MENU

If any one of the ABSCESS-WOUND is selected:

1 ROUT C & S
2 ANAEROBES
3 MYCOPLASMA CULTURE
4 CHLAMYDIA CULTURE
5 FUNGAL CULTURE
6 TB CULTURE/SMEAR
7 ATYPICAL TB CULTURE
8 VIRAL CULTURE
9 DIRECT EM
10 MASTER TEST MENU

Figure 40 l, m, n. Test menus for biopsies-tissues, tubing-tips, and abscess-wound specimens are shown here.

If STREPTOCOCCAL SEROLOGY is selected:

1 ASOT
2 ANTIDNASE
3 STREPTOZYME
4 STREPTODORNASE
5 STREPTOKINASE
6 ANTIHYALURONIDASE

If FUNGAL SEROLOGY is selected, the following diagnoses will be displayed for selection:

1 CANDIDIASIS/YEASTS
2 CRYPTOCOCCOSIS
3 HISTOPLASMOSIS
4 ASPERGILLOSIS
5 MUCOROMYCOSIS
6 BLASTOMYCOSIS
7 COCCIDIOIDOMYCOSIS
8 TORULOPSOSIS
9 SPOROTRICHOSIS
10 PARACOCCIDIOIDIMYCOSIS
11 FARMER'S LUNG
12 OTHERS*
13 UNKNOWN

*SPECIFY SUSPECTED DIAGNOSIS:

Figure 40 o, p. Detailed test menus for Streptococcal and fungal serology tests. The menus are displayed automatically when either one test is selected from the master menu.

If SYPHILIS SEROLOGY is selected:

1 RPR/KAHN/VDRL
2 MHA-TP
3 TPI
4 FTA-ABS

If VIRAL SEROLOGY is selected:

1 ADENOVIRUS
2 INFLUENZA
3 HEPATITIS
4 PARA INFLUENZA
5 CYTOMEGALO VIRUS
6 HERPSE SIMPLEX
7 MEASLES
8 RUBELLA
9 VARIOLA
10 RUBEOLA
11 EBSTEIN BAR VIRUS
12 ROTA VIRUS
13 OTHERS*

*SPECIFY SPECIFIC AGENT OF INTEREST:

If ANTIBIOTIC ASSAY is selected:

1 ANTIBIOTIC LEVEL
2 MIC/MBC LEVEL
3 SYNERGISTIC STUDIES
4 SERUMCIDAL-STATIC LEVEL

Figure 40 q, r, s. Detailed test menus for Syphilis, viral serology and antibiotic assays. The menus are displayed when these tests are selected from the master menu.

Result Entry Menus

1. After the result routine is initiated and the patient ID is entered, the computer will check the specimen type in the request record and will display the appropriate result menu for result entry.
2. Brackets are areas where results can be entered.
3. The cursor will always appear at the first bracket at the top of the menu. One should be able to skip to any other brackets in the menu by manipulating certain keys on the CRT keyboard.
4. Most results entered are in coded form that are automatically expanded to full text upon display and in the reports.
5. Abbreviated quantifiers such as: S-scant, F-few, M-moderate, V-many, H-heavy, etc., are used throughout the result entry menus.
6. Organism IDs are entered as 5 or 6 letter codes. One may use the first or first two letters of the genus name and 4 or 5 letters from the species name, etc. For example, Staphylococcus aureus may be entered as STAUER or SAUREU.
7. Depending on the organism ID entered, the appropriate sens panel will be displayed in the brackets directly below the organism bracket.
8. Sens results are entered either as: S-sensitive, I-intermediate, R-resistant.

9. All results entered are brightened in constrast to the displayed text which is dull.
10. Antibiotic results not usually reported for a particular organism are displayed in lower case letters. If one wishes to report these sens, one may type in a special character directly beside the sens result. this will indicate that the result is to be reported and the antibiotic name should automatically change to capital letters.
11. Organism ID can be updated by typing directly over the same bracket. The computer should store both IDs entered, however, only the updated ID will appear on display and in the report. Additional comments can be added beside the organism bracket.
12. Various comments can be entered via the function keys. In addition, the function keys can also cause additional menus to be displayed for selection. For example, the function key for 'ADD MORE ORGANISMS' will cause an extra set of organism result brackets to be displayed under the 2nd set of orgnaism brackets that are already on the screen.
13. All result menus are shown in figure 41. Some entry examples, designated by lower case letters, are included in the sputum menu in figure 41a.

RESULT MENU - SPUTUMS

COMMENTS:

NO GROWTH IN ( ) HOURS enter '24' or '48'
(q) MIXED GROWTH BACTERIA, NOT UNUSUAL FLORA q-quantifier

GRAM SMEAR RESULTS:

GM+B	(q)	GM-B	( )	EPITH	( )	TRICH	( )
GM+C	( )	GM-DC	(q)	POLYS	( )	NO TRIC	( )
MIXED	( )	NBS	( )	RBC	( )	YEASTS	( )
(comment)		( )		(comment)			

ORGANISM & SENSITIVITY RESULTS: *sens result to report

1. (q)	(psaeru)	(comment)		PSEUDOMONAS AERUGINOSA							
(KANA)	(r)	(COLY)	(s)	(GENT)	(s)	(TOBR)	(s)	(TIC)	(s)		
(ceph)	(r)	(tetra)	(r)	(amp)	(r)	(CHLOR)	(s*)	( )	( )		
( )	( )	( )	( )	( )	( )	( )	( )	( )	( )		
2. (q)	(staure)	(phage 29)		STAPHYLOCOCCUS AUREUS							
(PEN)	(s)	(METH)	(s)	(ERY)	(s)	(CEPH)	(s)	(AMP)	(s)		
(GENT)	(r)	(chlor)	(s)	( )	( )	( )	( )	( )	( )		
( )	( )	( )	( )	( )	( )	( )	( )	( )	( )		

FUNCTION KEY ENTRY:

1. ORGANISM DESCRIPTIONS MENU
2. COMMENTS MENU
3. ADD MORE ORGANISMS
4. SEND INTERIM REPORT
5. SEND FINAL REPORT
6. NEG FOR C. DIPHTH, GP A STREPT, S. AUREUS
7. IF SENS REQUIRED, CONTACT LAB IMMEDIATELY

Figure 41 a. A sputum result menu is shown here.

RESULT MENU - ANAEROBES

COMMENTS:

( ) OF MIXED ANAEROBIC BACTERIA
FOR FURTHER REPORT SEE ( )
FOR FURTHER CULTURE REPORT PLEASE SEE ( )

ORGANISM RESULTS:

( ) ANAEROBIC GRAM NEGATIVE BACILLI
( ) ANAEROBIC GRAM POSITIVE BACILLI
( ) MICROAEROPHILIC GRAM POSITIVE BACILLI
( ) ANAEROBIC GRAM POSITIVE COCCI
( ) ANAEROBIC NONSPORE-FORMING GRAM POSITIVE BACILLI

1. ( )( )( )( )( )( )( )( )( )( )( )( )

2. ( )( )( )( )( )( )( )( )( )( )( )( )

FUNCTION KEYS:

1. ORGANISM DESCRIPTION MENU
2. COMMENTS MENU
3. ADD MORE ORGANISMS
4. SEND INTERIM REPORT
5. SEND FINAL REPORT
6. IF ID REQUIRED, PLEASE PHONE LAB
7. CULTURE NEG FOR ACTINOMYCES
8. CULTURE NEG FOR CAMPYLOBACTER
9. CULTURE NEG FOR CLOST DIFFICILE

Figure 41 b. An anaerobes result menu is shown here.

RESULT MENU - THROATS

COMMENTS:

( ) MIXED GROWTH BACTERIA, NOT UNUSUAL FLORA

ORGANISM & SENSITIVITY RESULTS:

1. ( )( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )

2. ( )( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )

FUNCTION KEY ENTRY:

1. ORGANISM DESCRIPTIONS MENU
2. COMMENTS MENU
3. ADD MORE ORGANISMS
4. SEND INTERIM REPORT
5. SEND FINAL REPORT
6. NEG FOR C. DIPHTH, GP A STREPT.
7. IF SENS REQUIRED, CONTACT LAB IMMEDIATELY
8. CULTURE SHOWS NO GROWTH

Figure 41 c. A throat specimen result menu is shown.

RESULT MENU - NOSE

COMMENTS:

( ) MIXED GROWTH BACTERIA, NOT UNUSUAL FLORA

ORGANISM & SENSITIVITY RESULTS:

1. ( )( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )

2. ( )( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )

FUNCTION KEY ENTRY:

1. ORGANISM DESCRIPTIONS MENU
2. COMMENTS MENU
3. ADD MORE ORGANISMS
4. SEND INTERIM REPORT
5. SEND FINAL REPORT
6. NEG FOR C. DIPHTH, GP A STREPT, STAPH AUREUS
7. IF SENS REQUIRED, CONTACT LAB IMMEDIATELY
8. CULTURE SHOWS NO GROWTH

Figure 41 d. A nose specimen result menu is shown.

RESULT MENU - SWABS

COMMENTS:

NO GROWTH IN ( ) HOURS
NO GROWTH IN ( ) WEEK

GRAM SMEAR RESULTS:

GM+B	( )	GM-B	( )	EPITH	( )	TRICH	( )
GM+C	( )	GM-DC	( )	POLYS	( )	NO TRIC	( )
MIXED	( )	NBS	( )	RBC	( )	YEASTS	( )
( )		( )		( )			

ORGANISM & SENSITIVITY RESULTS:

1. ( )( )( )

RESULT MENU - STOOLS

ORGANISM & SENSITIVITY RESULTS:

1. ( )( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )

2. ( )( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )

FUNCTION KEY ENTRY:

1. ORGANISM DESCRIPTIONS MENU
2. COMMENTS MENU
3. ADD MORE ORGANISMS
4. SEND INTERIM REPORT
5. SEND FINAL REPORT
6. CULT NEG FOR TYPHOID, SAL & SHI, YERSINIA, CAMPYLOBACT
7. NO GROWTH IN 24 HOURS

Figure 41 f. A stool result menu is shown.

RESULT MENU - URINES

COLONY COUNT : 10X ( ) ORG/ML

ORGANISM & SENSITIVITY RESULTS:

1. ( )( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )

2. ( )( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( ) ( )( )

FUNCTION KEY ENTRY:

1. ORGANISM DESCRIPTIONS MENU
2. COMMENTS MENU
3. ADD MORE ORGANISMS
4. SEND INTERIM REPORT
5. SEND FINAL REPORT
6. MIXED GROWTH
7. NO GROWTH IN 24 HOURS

Figure 41 g. A urine result menu is shown.

RESULT MENU - GENITAL SPECIMENS

COMMENTS:

( ) MIXED BACTERIAL GROWTH, NOT UNUSUAL FLORA
( ) MIXED SKIN FLORA

GRAM SMEAR RESULTS:

GM+B	( )	GM-B	( )	EPITH	( )	TRICH	( )
GM+C	( )	GM-DC	( )	POLYS	( )	NO TRIC	( )
MIXED	( )	NBS	( )	RBC	( )	YEASTS	( )

ORGANISM & SENSITIVITY RESULTS:

1. ( )( )( )

RESULT MENU - BLOOD CULTURE

NO GROWTH AEROBIC/ANAEROBIC IN ( ) DAYS
NO GROWTH AEROBIC/ANAEROBIC IN ( ) WEEK

DIRECT SMEAR RESULTS

( ) SEEN IN ( ) TUBES SUBMITTED
( ) SEEN IN ( ) TUBES SUBMITTED

ORGANISM & SENSITIVITY RESULTS:

1. ( )( ) ISOLATED FROM ( ) TUBES SUBMITTED
( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( )

2. ( )( ) ISOLATED FROM ( ) TUBES SUBMITTED
( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( )
( )( ) ( )( ) ( )( ) ( )( )

FUNCTION KEY ENTRY:

1. ORGANISM DESCRIPTIONS MENU
2. COMMENTS MENU
3. ADD MORE ORGANISMS
4. SEND INTERIM REPORT
5. SEND FINAL REPORT
6. NO FURTHER WORK UNLESS LAB IS CONTACTED
7. NO FURTHER REPORT UNLESS ORGANISM ISOLATED

Figure 41 i. A blood culture result menu is shown.

```
                RESULT MENU - OVA & PARASITES
                -----------------------------

ORGANISM RESULTS:

1.  (  )(        )(   )
2.  (  )(        )(   )

CY-CYST              TR-TROPHOZITES              OV-OVA
S-SCANT        F-FEW          M-MODERATE        H-MANY

FUNCTION KEY ENTRY:

1.  ORGANISM DESCRIPTIONS MENU
2.  COMMENTS MENU
3.  ADD MORE ORGANISMS
4.  SEND INTERIM REPORT
5.  SEND FINAL REPORT
6.  NO OVA & PARASITES SEEN
7.  I.Q. FOR CONC, PLEASE SUBMIT ANOTHER SPECIMEN
8.  REPORT ON STOOL CONCENTRATE TO FOLLOW
```

```
              RESULT MENU - ANTIBIOTIC LEVELS

-------------------------------------------------------------
                  GENTAMICIN LEVELS
ACSN NR      PAT-ID -NAME
  REQD D&T           COL'D D&T          REC'D D&T
-------------------------------------------------------------

2345       58476638    DOE JOHN
  12JUL80 11:20     12JUL80 11:40     12JUL80 12:10
  LAST DOSE: 12JUL80 10:30          NEXT DOSE:12JUL80 15:30
  DOSAGE: 50 MG                     ROUTE: IV
  PRE/POST: POST                    OTHER ABS: PEN
  IDEAL COLLECTION TIME: 12JUL80 11:30
  GENTAMICIN LEVEL: (     ) UG/ML
```

Figure 41 j, k. An ova & parasite menu and an antibiotic level menu for result entry are shown here.

RESULT MENU - CIE

Counterimmunoelectrophoresis of C.S.F. specimen positive for ( )

1 Counterimmunoelectrophoresis of C.S.F. specimen negative for the following antigens:

- Hemophilus influenzae type b
- Neisseria meningitidis polyvalent gp A,B,C,D,X,Y,Z
- Streptococcus pneumoniae

RESULT MENU - URINE AB-COATED BACTERIA

1 COLONY COUNT >10X5 ORG/ML
2 COLONY COUNT <<10X4 ORG/ML
3 POSITIVE FOR ANTIBODY-COATED BACTERIA
4 NEGATIVE FOR ANTIBODY-COATED BACTERIA
5 ANTIBODY-COATED STUDIES NOT DONE
6 MIXED CULTURE - REPEAT SPECIMEN

Figure 41 l, m. A CIE result menu and an urine antibody-coated bacteria result menu are shown.

RESULT MENU - PERTUSSIS

1 BY DIRECT FLUORESCENT AB TEST NEG FOR B PERTUSSIS AND PARAPERTUSSIS. CULTURE TO FOLLOW

2 NEGATIVE REPORT. B PERTUSSIS & PARAPERTUSSIS NOT ISOLATED

3 B PERTUSSIS SEEN IN FLUORESCENT AB TEST

4 B PARAPERTUSSIS SEEN IN FLUORESCENT AB TEST

RESULT MENU - CHLAMYDIA & MYCOPLASMA

1 NO MYCOPLASMA PNEUMONIAE ISOLATED
2 NO MYCOPLASMA ISOLATED
3 MYCOPLASMA HOMINIS ISOLATED
4 MYCOPLASMA PNEUMONIAE ISOLATED
5 UREAPLASMA UREALYTICUM (T STRAIN) ISOLATED

CHLAMYDIA TRACHOMATIS ISOLATED IN:

6 IUDR-, DEXTRAN- TREATED McCOY CELLS
7 HeLa CELLS

LATEX AGGLUTINATION TEST FOR ANTIBODIES AGAINST MYCOPLASMA PNEUMONIAE:

TITRE (RECIPROCAL) OF PATIENT'S SERUM ( )
TITRE OF NEGATIVE CONTROL SERUM ( )

8 A FOURFOLD RISE IN TITRE OF PAIRED SERA IS CONSIDERED TO BE OF DIAGNOSTIC IMPORTANCE

M.I.C. of ( ) is ( )

Figure 41 n, o. A Pertussis result menu, and a Chlamydia and Mycoplasma result menu are shown.

ORGANISM DESCRIPTIONS MENU

( ) HEMOLYTIC STREPT TXA RESIST PROB NOT A
( ) HEMOLYTIC STREPT TXA SENS PRESUMP A GPING TO FOLLOW
( ) BIOCHEM RX SUGG G.C.
( ) N. GONORRHOEAE CONFIRMED BY IFA TEST
( ) PSEUDO SP OF FLUORESCENS GP
( ) PRESUMPTIVE STAPH AUREUS
( ) STAPH AUREUS CONFIRMED AS PREVIOUSLY REPORTED
( ) YEAST ISOLATED GERM TUBE POS PRESUMP C. ALBICANS
( ) YEAST ISOLATED GERM TUBE NEG
( ) ARE ANAEROBIC ORGANISMS
( ) ARE AEROBIC ORGANISMS
( ) STAPH SPECIES, COAG-VE, DNASE+VE, MANN+VE

Each of these descriptions refers to a particular organism, therefore the appropriate organism number has to be entered in the bracket beside the desired description.

COMMENTS MENU

1. AFTER FURTHER INCUBATION
2. SPECIMEN FORWARDED TO TB
3. SPECIMEN FORWARDED TO MYCOLOGY
4. SENS COMMENT A
5. SENS COMMENT B
6. SENS COMMENT C
7. SPECIMEN WAS NOT LABELED AS TO TIME TAKEN
8. SPECIMEN NOT LABELED AS TO DATE TAKEN
9. SPECIMEN NOT LABELED AS TO DATE/TIME TAKEN
10. NO SPECIMEN RECEIVED

*DETAILED SITE DESCRIPTIONS REQUIRED

Figure 41 p, q. The organism description menu and the comments menu are shown here. these are displayed automatically when prompted by pressing certain function keys as indicated by the result menus.

Lists

Check-in List

1. This list is to be the hard-copy option from the check-in routine. The requests should be sorted either by the test names, accession numbers, or patient names/ID's.
2. The list should contain all the requests that are at a particular status specified by the user.
3. The headings should include at least the following:
   a. Patient ID.
   b. Patient name.
   c. Accession number.
   d. Location.
   e. Test name.
   f. Date/time requested.
4. A proposed layout for this list is given in figure 42.

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DEPARTMENT OF MICROBIOLOGY

CHECK-IN LIST
AS AT: 03JUL80 13:50

NR	TEST NAME, REQD D&T	ACSN NR COL'D D&T	PATNT-ID -NAME REC'D D&T	SPECIMEN	STATUS
1	GENTA LEVEL 03JUL80 11:30	AA6430 03JUL80 12:00	3967583 MARION JOSEPH -	BLOOD	COL'D
2	ROUT C & S 03JUL80 07:00	S26843 03JUL80 07:30	4724687 PAPPERNICK MARYANNE 03JUL80 08:00	SPUTUM	WPOOL
3	C.C./C & S 03JUL80 11:30	U82435 -	9876543 KENDLEWICK JOHN -	URINE M.S.	PENDG

NR	ACSN NR REQD D&T	PATNT-ID -NAME COL'D D&T	TEST NAME REC'D D&T	SPECIMEN	STATUS
1	A46837 03JUL80 11:30	3784296 DICKENS JOAN 03JUL80 11:45	GENTA LEVEL 03JUL80 12:00	BLOOD	REC'D
2	DU84293 02JUL80 13:20	4372638 BLACKSTONE JOHNATHAN 02JUL80 13:40	ROUT C & S 02JUL80 15:10	THROAT SWAB	WPOOL
3	MU6839 03JUL80 11:25	4825791 HNATKO WILLIAMS 03JUL80 11:10	ROUT C & S -	BURN SITE SHOULDER L	PENDG

NR	PATNT-ID -NAME REQD D&T	COL'D D&T	ACSN NR REC'D D&T	TEST NAME SPECIMEN	STATUS
1	3847563 SMITH DAVID 02JUL80 11:50	02JUL80 11:20	MU9567 02JUL80 13:00	ROUT C & S URETHRAL SWAB	WPOOL
2	4837362 CHAMBERLAIN ROGER 01JUL80 15:00	-	S38262 -	ROUT C & S SPUTUM	PENDG

Figure 42. A proposed layout of the Check-in list is shown here. Explanatory Explanatory notes: NR - number, ACSN NR - accession number, PATNT - patient, REQD D&T - requested date & time, COL'D D&T - collected date & time, REC'D D&T - received date & time.

Overdue List

1. This list should contain all requests that:
   a. have not had a preliminary report within a specified time period.
   b. have not had the final report issued within a specified time period.
2. Each request listed should contain the same headings as the Check-in List, plus its collected and received date/time, and status.
3. A proposed layout for this list is given in figure 43.

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DEPARTMENT OF MICROBIOLOGY

OVERDUE-LIST
AS OF: 05JUL80 15:30

NO PRELIMINARY REPORTS:

TEST NAME REQD D&T	ACSN NR PATNT-ID -NAME COL'D D&T	REC'D D&T	REP'D D&T	SPECIMEN
ROUT C & S 02JUL80 12:00	MU38657 DICKENSON CHARLES 02JUL80 11:00	02JUL80 14:00	-	NOSE SWAB
ROUT C & S 03JUL80 13:00	DU89736 2736254 WEAVER DENNIS 03JUL80 12:40	03JUL80 14:20	-	THROAT SWAB

NO FINAL REPORTS:

TEST NAME REQD D&T	ACSN NR PATNT-ID -NAME COL'D D&T	REC'D D&T	REP'D D&T	SPECIMEN
ROUT C & S 01JUL80 12:00	MU8556 2345678 SHOGUN TAKASHIMARU 01JUL80 12:00	01JUL80 13:00	02JUL80 14:00	BURN SITE
ROUT C & S 29JUN80 13:10	MU8765 6543217 PICKENSFIELD SUSAN 29JUN80 13:20	29JUN80 15:00	30JUN80 14:00	MOUTH SWAB
C.C./C & S 30JUN80 12:00	U2345 5735384 WHITEHORSE PETER 30JUN80 11:40	30JUN80 12:00	01JUL80 14:00	URINE-CATH

Figure 43. A proposed layout of the Overdue list is shown here. Explanatory notes: NR - number, ACSN NR - accession number, PATNT - patient, REQ D&T - requested date & time, COL'D D&T - collected date & time, REC'D D&T - received date & time, REP'D D&T - reported date & time.

Positive Culture Summary List

1. This list should print the patient names who, within a specified time period,
   a. have culture results containing pre-defined organism results.
   b. have certain pre-defined significant requests with positive culture results.
2. The headings in this list should be the same as the Overdue List, plus it should give the names of the organisms.
3. A proposed layout for this list is given in figure 44.

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DEPARTMENT OF MICROBIOLOGY

POSITIVE CULTURE SUMMARY LIST

FROM: 01JUL80 TO: 30JUL80 RUN D&T: 31JUL80 12:30

TEST NAME / REQD D&T	PATNT-ID -NAME / COL'D D&T	REC'D D&T	ACSN NR / REP'D D&T	SPECIMEN
BLOOD CULTURE 03JUL80 12:30	3627256 HIGGINS WARREN 03JUL80 12:20	03JUL80 13:00	BC36923 06JUL80 16:00	BLOOD
MODERATE ESCHERICHIA COLI				
ROUT C & S 09JUL80 12:00	5746241 DICKENSON JOAN 09JUL80 12:10	09JUL80 12:30	MU46823 10JUL80 16:30	C.S.F.
MODERATE STREPTOCOCCUS PNEUMONIAE				
ROUT C & S 12JUL80 07:00	1234567 UNFORTUNATO BABY EWING 12JUL80 08:00	12JUL80 09:00	EU3896 15JUL80 12:45	FECES
HEAVY GROWTH VIBRIO CHOLERAE				

Figure 44. A proposed layout of the Positive culture summary list is shown. Explanatory notes: NR - number, ACSN NR - accession number, PATNT - patient, REQ D&T - requested date & time, COL'D D&T - collected date & time, REC'D D&T - received date & time, REP'D D&T - reported date & time.

Referral List

1. There should be a separate list for each type of referral test.
2. Each list should contain all the referral requests that have been received and forwarded to Prov Lab. It should also give the total number of specimens submitted.
3. The list should have the same headings as the Overdue List.
4. A proposed layout for this list is given in figure 45.

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PROVINCIAL LABORATORY REFERRAL LIST

TEST NAME: TB CULT/SM AS OF: 13JUL80 12:30

PATNT-ID -NAME	ACSN NR	STATION	SPECIMEN
REQD D&T	COL'D D&T	REC'D D&T	
2637221 HUSSEIN MOROCCO	S283745	3J1024	SPUTUM
12JUL80 12:00	12JUL80 13:00	13JUL80 07:00	
6543215 POPPINS MARYANNE	U8976	3J1321	URINE
13JUL80 10:00	13JUL80 10:12	13JUL80 11:00	
2817152 DIECKENSFIELD CHALETTE	U1827462	4J3921	URINE M.S.
13JUL80 11:00	13JUL80 11:30	13JUL80 12:00	

. . . . .

. . . . .

. . . . .

. . . . .

TOTAL NUMBER OF SPECIMENS SUBMITTED : 12

Figure 45. A proposed layout of the Referral list is shown.

Reject Summary List

1. This list should contain all the 'reject' comments and the stations involved that have been accumulated over a period of time, and the total number of each type of comment involved.
2. The list should be sorted by the periods specified by the user. The frequencies tallied should be printed in descending order.
3. A proposed layout for this list is given in figure 46.

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DEPARTMENT OF MICROBIOLOGY

REJECT SUMMARY LIST

FROM: 01JUL80 TO: 30JUL80 RUN D&T: 01AUG80 12:00

CODED COMMENT	STN	TOTAL	SUB-TOTAL
INSUFFICIENT QUANTITY FOR ANALYSIS	3J	8	
	4J	7	
	5J	2	
	1K	1	
	32	1	
	33	1	
	34	1	(21)
SPECIMEN CONTAMINATED WHEN RECEIVED	3J	6	
	2J	2	
	4K	1	
	3K	1	
	2K	1	
	31	1	(12)

STN	TOTAL	CODED COMMENT	(SUB-TOTAL)
3J	7	SPECIMEN CONTAMINATED WHEN RECEIVED	(6)
		INSUFFICIENT QUANTITY FOR ANALYSIS	(1)
2J	5	SPECIMEN CONTAMINATED WHEN RECEIVED	(1)
		SPECIMEN UNLABELLED	(1)
		INAPPROPRIATE SPECIMEN SUBMITTED	(1)
		DUPLICATE SPECIMENS	(1)
		WRONG CONTAINER	(1)

Figure 46. A proposed layout of the Reject summary list is shown.

Result Summary List

1. This list should contain all the requests and results specified by the user for a particular time period.
2. Each set of test results should be identified by the following information:
   a. Test name.
   b. Patient's name and ID.
   c. Location.
   d. Accession number.
   e. Specimen/source.
   f. Requested date/time.
   g. Collected date/time.
   h. Received date/time.
   i. Report date/time (if any).
   j. Status.
   k. Results.
3. In addition, it should also be optional to list the results on selected routine C & S requests that have corresponding Anaerobic cultures requested as well.
4. This list is to be printed in the Dept whenever it is needed.
5. A proposed layout for this list is given in figure 47.

RESULT SUMMARY LIST
TEST NAME: ROUT C & S

AS OF: 10JUL80 13:50

PATNT-ID -NAME		ACSN NR	SPECIMEN	STATUS
REQD D&T	COL'D D&T	REC'D D&T	REP'D D&T	
3748362 WHITBY JOHN		MU27361	BURN SITE L LEG	PRELIM
07JUL80 13:50	07JUL80 13:20	07JUL80 16:20	08JUL80 13:40	

GRAM SMEAR....

MODERATE PUS CELLS
FEW GRAM NEGATIVE BACILLI

CULTURE....

MODERATE GROWTH OF COLIFORMS

2516241 HIGGINS DONALD		S182651	SPUTUM	WPOOL
09JUL80 12:30	09JUL80 12:20	09JUL80 14:00	-	

GRAM SMEAR....

FEW EPITHELIAL CELLS
MODERATE POLYMORPHS
MODERATE GRAM POSITIVE DIPLOCOCCI

CULTURE....

MODERATE GRAM POSITIVE COCCI
MODERATE GRAM NEGATIVE COCCOBACILLI

Figure 47. A proposed layout of the Result summary list is shown here.

Verify List

1. This list should contain any results that need to be verified.
2. Its headings should be the same as the Result List.
3. A proposed layout for this list is given in figure 48.

VERIFY LIST
TEST NAME: ROUT C & S
AS OF: 10JUL80 13:50

PATNT-ID -NAME / REQD D&T	COL'D D&T	ACSN NR / REC'D D&T	SPECIMEN / REP'D D&T	STATUS
3643212 MOLBY DICKENS		MU1234	BURN SITE R LEG	PRELIM
07JUL80 13:50	07JUL80 13:20	07JUL80 16:30	09JUL80 13:20	

GRAM SMEAR....

MODERATE POLYMORPHS
FEW GRAM NEGATIVE BACILLI

CULTURE....

MODERATE GROWTH OF COLIFORMS

2736152 DKCKENSON MARYANNE		S23456	SPUTUM	INTERIM
09JUL80 12:30	09JUL80 12:20	09JUL80 14:00	11JUL80 12:00	

GRAM SMEAR....

FEW EPITHELIAL CELLS
MODERATE POLYMORPHS
MODERATE GRAM POSITIVE DIPLOCOCCI

CULTURE....

MODERATE GRAM POSITIVE COCCI
FEW COLIFORMS

Figure 48. A proposed layout of the Verify list is shown here.

Worklist

1. This list is used for antibiotic assays.
2. It lists the accession number of the specimens received for a particular test that is to be performed.
3. The status of the request upon the generation of the worklist will be changed from 'WORKPOOL' to 'WORKLIST'.
4. A proposed layout of this list is given in figure 49.

```
                    WORK LIST  #192
                    GENTAMICIN LEVEL

                  AS OF: 01JUL80 13:50

ACSN NR   PATNT-ID -NAME                              STATION
  REQD D&T        COL'D D&T        REC'D D&T
-------------------------------------------------------------


4567      1928361 JOHNSTON JONA                        3J012
  01JUL80 11:30  01JUL80 11:20  01JUL80 12:40
  LAST DOSE: 01JUL80 09:30    NEXT DOSE: 01JUL80 16:30
  DOSAGE: 50 MG/KG            ROUTE: IV
  PRE/POST: POST              OTHER ABS: -
  IDEAL COLLECTION TIME: 01JUL80 11:15
    GENTAMICIN LEVEL: (     ) UG/ML


4660      8473611 KAHN KANGHIS                         4K104
  01JUL80 12:10  01JUL80 12:15  01JUL80 13:10
  LAST DOSE: -                NEXT DOSE: 01JUL80 12:30
  DOSAGE: 30 MG/KG            ROUTE: IV
  PRE/POST: PRE               OTHER ABS: PEN G
  IDEAL COLLECTION TIME: 01JUL80 12:10
    GENTAMICIN LEVEL: (     ) UG/ML
```

Figure 49. A proposed layout of the Worklist is shown here.

Reports

Infection Summary Reports

1. The reports should allow the user to list reports according to any one of the following parameters:
   a. Verified & finalized results within a specified time period.
   b. All culture results within a specified time period.
   c. All positive or negative cultures within a specified time period.
2. The reports should be sorted according to the location, organism, and specimen/source parameters in the order so specified by the user.
3. One should also be able to specify only selected locations, organisms, and specimens/sources.
4. The proposed layouts for these reports are given in figure 50.

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DEPARTMENT OF MICROBIOLOGY

INFECTION SUMMARY REPORT

FROM: 01JUL80 to 10JUL80

RUN D&T: 10JUL80 23:50

ORGANISM	STATION	SPECIMEN/SOURCE	PATNT-ID -NAME
STAPHYLOCOCCUS AUREUS	3J1024	URINE M.S.	2718361 WHITEHORSE BABY JOE
	3J1043	WOUND ABDOMEN	3826143 ANDERSON JOHN

STATION	ORGANISM	SPECIMEN/SOURCE	PATNT-ID -NAME
3J2104	PSEUDOMONAS FLUORESCENS	WOUND LEG L	1234567 DICKENSON MARYANNE
		URINE M.S.	3245132 WEINSTEIN HERBERT

STATION	PATNT-ID -NAME	SPECIMEN/SOURCE	ORGANISM
32102	4735142 WILEY STEVENS	SPUTUM	STREPTOCOCCUS GROUP A
33105	5847831 STEVENSON HOLLY	THROAT	STREPTOCOCCUS GROUP A

SPECIMEN/SOURCE	ORGANISM	STATION	PATNT-ID -NAME
BLOOD	KLEBSIELLA SPECIES	32102	5827112 WOODHART KIMBERLY

Figure 50. Examples of the Infection Summary Reports, sorted in different ways, are shown here.

Patient's Cumulative Report

1. The user must be able to specify:
   a. the time period.
   b. the number of copies.
   c. the test name(s).
   d. the patient name(s).
   e. the station number(s).
2. The report should be sorted by locations, patients in alphabetical order, tests requested in chronological order, and specimens/sources.
3. A proposed layout for this report is given in figure 51.

```
                UNIVERSITY OF ALBERTA HOSPITAL
                  DEPARTMENT OF MICROBIOLOGY
                  PATIENTS CUMULATIVE REPORT
                     AS OF: 01JUL80 12:30

4857463 DICKENS JOAN EDITH          F 34                    3J102A

TEST NAME          SPECIMEN/SOURCE              ACSN NR    STATUS
  REQD D&T         COL'D D&T       REC'D D&T      REP'D D&T
-------------------------------------------------------------------

ROUT C & S         SPUTUM                       S34561     PRELIM
  01JUL80 10:30    01JUL80 09:30   01JUL80 12:30  01JUL80 13:30

  GRAM SMEAR.....

    MODERATE NUMBERS OF GRAM POSITIVE COCCI
    MODERATE POLYMORPHS

  CULTURE.....

    TO FOLLOW


4857463 DICKENS JOAN EDITH          F 34                    3J102A

TEST NAME          SPECIMEN/SOURCE              ACSN NR    STATUS
  REQD D&T         COL'D D&T       REC'D D&T      REP'D D&T
-------------------------------------------------------------------

ROUT C & S         SPUTUM                       S34561     PRELIM
  01JUL80 10:30    01JUL80 09:30   01JUL80 12:30  01JUL80 13:30

  GRAM SMEAR.....

    MODERATE NUMBERS OF GRAM POSITIVE COCCI
    MODERATE POLYMORPHS
    FEW EPITHELIAL CELLS

COLONY COUNT/C&S   URINE - M.S.                  U59584     **FINAL
  08JUL80 12:00    08JUL80 11:50   08JUL80 12:30  10JUL80 14:00

  COLONY COUNT: 10X5 ORG/ML

  CULTURE.....
    CULTURE MIXED.  NO FURTHER WORK DONE.

***MICROBIOLOGY CUMULATIVE REPORT***27JUN80-01JU180***
```

Figure 51. Two patient cumulative reports on the same patient are shown here.

Patient Inquiry Report

1. This report is to be the hard-copy option from the patient inquiry routine.
2. The report should be sorted according to any one of the parameters provided by the user.
   a. Test names.
   b. Patient names/IDs.
   c. Accession numbers.
3. A proposed layout for this report is given in figure 52.

```
3762537 GOLDFINGER JOHNATHAN      M 3J102          JAUNDICE

 TEST NAME      SPECIMEN/SOURCE                STATUS  ACSN NR
   REQD D&T       COL'D D&T      REC'D D&T       REP'D D&T
-------------------------------------------------------------

 ROUT C & S     WOUND SWAB SHOULDER LEFT     INTERIM MU12345
   07JUL80 12:00  07JUL80 11:30  07JUL80 13:00  08JUL80 12:10

   GRAM SMEAR....

     MODERATE POLYMORPHS
     MODERATE GRAM NEGATIVE BACILLI

   CULTURE....

     MODERATE GROWTH PSEUDOMONAS AERUGINOSA
          KANA S  GENT S  TOBRA S  TICAR S  CHLOR S


C.C./C & S     URINE M.S.                     **FINAL U6453

   08JUL80 12:00  08JUL80 11:50  08JUL80 12:30  09JUL80 14:00

   COLONY COUNT  10x5 ORG/ML

   CULTURE MIXED.  NO FURTHER WORK DONE.


ROUT C & S     SPUTUM                         PRELIM  S58461

   07JUL80 12:00  07JUL80 11:30  07JUL80 13:30  08JUL80 12:00

   GRAM SMEAR....

     MODERATE GRAM POSITIVE DIPLOCOCCI

   CULTURE....

     MODERATE GROWTH STREPTOCOCCUS PNEUMONIAE
     HEAVY GROWTH YEASTS - GERM TUBE NEGATIVE

         ***MICROBIOLOGY LAB REPORT***AS OF-09JUL80***
```

Figure 52. A proposed layout of the CRT screen format for the Patient Inquiry routine. The optional hard copy should have the same format as above.

Patient's Daily Report

1. This report should be sorted the same way as the Patient's Cumulative Report, except that only the tests with new results are printed.
2. A proposed layout for this report is given in figure 53.

UNIVERSITY OF ALBERTA HOSPITAL
DEPARTMENT OF MICROBIOLOGY
PATIENTS DAILY REPORT

3837131 CHAMBERLAIN MEREDITH F 34 3J124

TEST NAME / REQD D&T	SPECIMEN/SOURCE / COL'D D&T	REC'D D&T	ACSN NR / REP'D D&T	STATUS
ROUT C & S 01JUL80 10:30	SPUTUM 01JUL80 09:30	01JUL80 12:30	S38261 01JUL80 13:30	PRELIM

GRAM SMEAR....

MODERATE GRAM POSITIVE COCCI
MODERATE POLYMORPHS
FEW EPITHELIAL CELLS
MODERATE YEASTS

CULTURE....

TO FOLLOW

MICROBIOLOGY DAILY REPORTAS OF-02JUL80***

Figure 53. A proposed layout of the Patients Daily Report is shown here.

Specimen Tally Report

1. This report should be sorted by the types of specimens and their categories that have been requested during a specified period.
2. The report should be broken down by the months and be cumulative for the year, i.e. giving the total for each month as well as for the whole year.
3. A proposed layout for this report is given in figure 54.

UNIVERSITY OF ALBERTA HOSPITAL
DEPARTMENT OF MICROBIOLOGY

SPECIMEN TALLY REPORT

FROM: 01JAN80 TO: 30JUN80 RUN D&T: 30JUN80 12:30

SPECIMEN/SOURCE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
AUGER	36	24	58	56	72	60	-	-	-	-	-	-	215
SPUTUM	362	382	345	584	394	475	584	684	-	-	-	-	4930
URINE	483	594	584	345	543	675	432	-	-	-	-	-	10293
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.	.	.	.	.	.	.	.	.	.	.	.	.	.
TOTAL	6970	6059	30219	4059	6059	4843	4324	.	.	.	.	.	594829

Figure 54. A proposed layout of the specimen tally report.

Susceptibility Profile Reports

A batch program is already in operation for generating these reports. For details see the report layouts in the documentation for Stride 228. It is hoped that the existing program can be attached to the system with little modification so it can provide up-to-date information for the lab staff upon request.

Workload Statistics Report

1. This report should be sorted by the test names, and should give the total work units for each test, as well as the total of all tests.
2. The figures should be cumulative and broken down by the month, with a total printed at the end of the year.
3. A proposed layout of this report is given in figure 55.

UNIVERSITY OF ALBERTA HOSPITAL
DEPARTMENT OF MICROBIOLOGY

WORKLOAD STATISTICS REPORT

FROM 01JAN80 TO: 31JUL80 RUN D&T: 01AUG80 12:30

TEST NAME (UNIT VALUE)	JAN	FEB	MAR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
ROUT C & S	2930	5960	3849	3931	7069	5849	.	.	.	.	.	96548
(35)	(59480)	(43030)	(49305)	(50439)	(30495)	(23825)						
C.C./C & S	782	965	652	486	732	120	.	.	.	.	.	3598
(42)	(9654)	(12950)	(1296	(2965Z)	(9642)	(5020)	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
MONTHLY TOTAL	649	6492	6945	.	.	.	.	.	.	.	.	.
	(76895)	(23459)	.	.	.	.	.	.	.	.	.	.

TOTAL TESTS TO-DATE: 9857493 TOTAL UNITS TO-DATE: 60594737

Figure 55. A proposed layout of the workload statistics report is shown here.

Data Storage Requirements

Input Data Volume

The Microbiology Dept processes approximately 100,000 specimens annually[7]. A breakdown of the test procedures performed on these specimens is given in figure 56. In addition, an average of 35,000 specimens are referred to the Provincial Laboratory of Public Health each year . A table listing the actual number of referral specimens sent during a six month period is shown in figure 57.

At the present moment, the total workload increases at about 5% per year. Therefore, the anticipated workload for the next 3 to 5 years will be approximately between 115,000 to 125,000 specimens.

Input Data Characteristics

The duration of each test procedure may vary depending on the type of specimen and organisms involved. Therefore, a survey was carried out to determine the length of time required to complete a test for each type of test procedure. This was done by examining all test requests that were processed in the month of January 1980, and counting the number of days it took for the tests to be completed. The results of this survey are shown in figure 58.

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[7]For details, refer to the 'Assessment report, revised version'.

Test Procedures	1977	1978	1979
sputum culture	9085	7927	7979
urine culture	2757	2930	2781
urine colony count	22229	22706	23129
nose & throat culture	9213	9465	9068
swabs & body fluid cultures*	27162	26425	26992
enterics (stools) total	2723	3333	3782
breakdown: c & s	1235	1943	2040
o & p	1320	2253	2480
giardia	168	214	413
scotch tape			13
Genital tract culture*	2176	2024	2601
Post mortem culture*	175	126	152
W.W.Cross culture*	2972	3579	4171**
Blood culture*	5657	6708	7202
Antibiotic assay	1232	2633	4028**
Mycoplasma culture	1225	1195	821
Bordetella culture	676	210	342
Urine antibody coated	60	150	84
Electron microscopy	136	116	81
Hospital hygiene culture	4597	3123	3320
CIE	205	190	205
Slide Agglutination test			44
C.F. quantitation			169
BCG viability study			2
Aerobic & anaerobic colony count			52
Total	92442	92842	97005

*Anaerobic cultures are included.
**Likely to still increase substantially in the near future.

Figure 56. A breakdown of microbiology test procedures performed by the Microbiology Dept during the years indicated. The numbers in each column represent the total number of tests or specimens processed in that year.

Procedures	Nov79	Dec79	Jan80	Feb80	Mar80	Apr80
Mycology	120	242	216	172	155	111
TB	374	370	464	311	294	271
Path E.coli	226	239	198	218	288	219
Widals	7	8	11	6	9	9
ASOT	21	13	18	18	12	25
Virology	722	617	905	728	671	754
Syphilis serol.						
Routine	1521	1332	1758	1587	1613	1456
FTA	14	3	11	9	11	6
MHA	48	31	44	36	38	64
Col. gold	6	4	5	6	9	9
Pandy	4	4	5	4	9	9
Total no. sent	3063	2863	3635	3095	3109	2933

Figure 57. Total number of referral tests sent to the Provincial Laboratory by the Microbiology Dept. of the U. of A. Hospital. The numbers represent the total number of specimens sent for a particular test procedure.

Figure 58. Summary of length of time required to complete a test for each type of microbiology test procedure at the University Hospital.

TEST NAME	3 DAYS OR LESS	4 TO 6 DAYS	7 TO 10 DAYS	11 TO 14 DAYS	15 TO 21 DAYS	OVER 3 WEEKS
SPUTUM CULTURE	54	39	5	1	1	-
URINE CULTURE	80	18	2	-	-	-
URINE COLONY COUNT	81	16	2	1	-	-
NOSE & THROAT CULTURE	81	17	1	1	-	-
MISC. CULTURE EXCL. ANAEROBE	51	28	10	5	5	1
ANAEROBE CULTURE	37	33	18	10	1	1
O & P EXAM STOOL CULTURE	9	30	26	18	11	6
GENITAL TRACT CULTURE	56	35	8	1	-	-
W.W.CROSS CULTURE	55	28	6	9	1	1
ANTIBIOTIC ASSAY	100	-	-	-	-	-
MYCOPLASMA & CHLAMYDIA C.	-	-	50	25	-	25
CIE, SLIDE AGGLUTINATION	100	-	-	-	-	-
URINE ANTIBODY COATED BACT	100	-	-	-	-	-
C.F. QUANTITATION	-	50	50	-	-	-
BLOOD CULTURE	-	-	18	7	72	3
ELECTRON MICROSCOPY	99	18	12	5	6	2
TOTAL (%)	56	18	12	5	6	2

Data Security

Access to all types of data in this system must be limited to authorized personnel only. The level of authority must be clarified as to the types of operations each level is allowed. A proposed security system for data access is described in figure 59.

1. Full access to the system must be limited only to levels 1 & 2.
2. Programmers from the Computing Services Dept should be allowed full access of all data during the development, implementation, and the testing phases. Thereafter, their level of access should be limited only to the system programs.
3. All computer procedures must require authority clearance when they are initiated. Persons with lower authority than designated for the particular procedure will be denied access.
4. A proposed authority level requirement for each computer procedure given in figure 60.

POSITION HELD	AUTHORITY LEVEL	ADMIT PATIENT	REQUEST TEST	ENTER RESULTS	VERIFY RESULTS	PRINT REPORTS	ACCESS RESULTS	MODIFY SYSTEM
PROGRAMMERS	1*							X
DIRECTORS AND CHIEF TECHS	2	X	X	X	X	X	X	
SENIOR TECHS	3		X	X	X	X	X	
JUNIOR TECHS	4		X	X		X	X	
MEDICAL AND NURSING STAFF	5	X	X			X	X	
ADMITTING STAFF	6	X						

Figure 59. A proposed security system for data access at the Microbiology Department of the University Hospital. *See 2 of previous page.

COMPUTER PROCEDURES	PERMITTED AUTHORITY LEVELS
1. CANCEL ROUTINE	2, 3, 4
2. CHECK-IN ROUTINE	2, 3, 4
3. PRINT ROUTINE	2, 3, 4, 5
4. INQUIRY ROUTINE	2, 3, 4, 5
5. RESULT ENTRY ROUTINE	2, 3, 4
6. RESULT VERIFY ROUTINE	2, 3
7. TEST REQUEST ROUTINE	2, 3, 4, 5

Figure 60. A proposed authority level requirement for each computer procedure in the Microbiology Department at the University Hospital.

System Limitations

1. Microbiology results are limited to the pre-defined phrases in the data base. Unusual results are to be entered as free-text comments.
2. Result entry is not truly on-line, i.e. results are still recorded on worksheets and are transcribed into the computer in batches via CRT's. Therefore, there is still a certain degree of time delay and duplication of work in recording results.
3. Results are accessible to doctors and nurses only after they have been verified by senior lab staff. Again, this accessibility is dependent on the rate at which results are verified in the laboratory.
4. Patient records remain on-line for only a certain period of time, after which they are purged onto magnetic tape for permanent storage. This means the retrieval of data that are no longer on-line has to be either through special request from the Computing Centre or through Medical Records.
5. Data security may be difficult to maintain and enforce because of constant staff-turnover. Besides, printed reports can still be easily accessible by some means, especially the patient reports on the nursing stations.

Manual Backup System

The 'Tandem' computer system used at the University Hospital contains three central processing units (CPU's) that operate simultaneously and act as a built-in backup for

each other. However, in case of complete computer failure, the following protocols are to be followed:

1. If computer down-time is expected to be less than 24 hours:
   a. Requisitions are to be used for requesting on the nursing stations.
   b. test requests are to be recorded in a daily log book. Accession number is assigned to each request accordingly. These numbers are in numerically ascending order along with the proper letter code.
   c. The accession number should be written on the back of each plate as well as the worksheet.
   d. Only urgent results are phoned, the remaining are delayed until the computer functions again.
   e. When the computer functions again, results from worksheets are entered and reports are generated immediately. Requests that have not been entered are entered at this time.
2. If computer down-time is expected to be 24 hours or longer:
   a. Requisitions are to be used for requesting on nursing stations.
   b. Requests are entered in a daily log book. Accession number is assigned to each request accordingly.
   c. The accession number should be written on the back of the plates. The requisition is to be used for REPORTING.

d. Results are recorded onto the requisitions and reports are sent whenever necessary, as well as at scheduled hours.

e. When the computer functions again, all data are entered when convenient.

Constraints & Alternatives

Scenario 2 - all but no wand readers in lab

Patient IDs or accession numbers are punched-in via CRT keyboard in order to retrieve the appropriate records.

Scenario 3 - no computer equipment on stations

All processes are the same as in the proposed physical system models except the following:

1. Nursing personnel collect specimens according to requests.
2. Requisitions are filled out accordingly by hand.
3. Upon receiving the specimen and requisition in the lab, the test is requested via CRT by tech.
4. As soon as new results are available, they are printed as daily reports and distributed to nursing stations via the telelift system.
5. Designated stations and medical staff will also get periodic cumulative reports OR upon requests when there is any new result available.

D. SUMMARY OF IMPACTS

Software Impacts

1. All computer procedures in the system should be developed and maintained by designated personnel in the Computing Services Dept.
2. Operator's manual or user's manual must be available in sufficient quantity for distribution in the Microbiology Dept. Complete documentation, including programmers' manual and system's manual, etc., must be accessible on request by authorized personnel from the Microbiology Dept.
3. The Microbiology Dept, as a user, must be able to specify any modifications that are necessary in the system once it is operational. This should be done by submitting written requests to the Computing Services Dept which will then act upon the request depending on the priority.
4. A system maintenance schedule should be set up for periodic system modifications. A suggested time period is every 3 months in the first 2 years post-implementation, and every six months thereafter.

Organizational Impacts

1. During the initial developmental phase, the Microbiology Dept should assign at least one senior staff member to act as the liaison officer between the laboratory and the Computing Services Dept.
   a. This person should be familiar with both the

laboratory routines and the design of the reporting system. The function of this person should be to provide the programmer with any information required, assist in setting up the data base and in documenting the system, etc.

b. When the system is fully developed, the liaison officer should also be responsible for assisting the implementation and testing of the system.

c. Because of the responsibility involved, the liaison officer should be relieved from routine duties at least during the implementation and testing of the system. After the system is 'on-live', the liaison officer should remain as the resource person for the laboratory.

2. The remaining staff should at least be familiar with the basic organizational and operational aspects of the information system. This should be through training sessions prior to computerization as well as experience with the system once it is operational.

3. All secretaries within the Microbiology Dept should be re-trained to become data processing clerks and be responsible for data processing. It is anticipated that when the system becomes fully operational, fewer secretaries would be needed.

4. Doctors and nurses are to be trained to use the CRT's for test requesting and data retrieval.

Operational Impacts

1. The process of test requesting and specimen labeling on nursing stations is changed drastically. Therefore, protocols outlining the proper procedures should be developed and distributed to each station.
2. The processing of specimens in the mail room is modified to include specimen check-ins ,labeling, and generating referral lists, etc.
3. All culture results have to be recorded onto pre-printed worksheets (also see post-implementation developments no.2 on page 257 that follows).
4. Techs should be encouraged to enter data via CRT's if possible.
5. The working routines may require re-scheduling so as to avoid peak hours when CRT's usage becomes heavy. A survey may be required to determine the ideal schedule that can bring about the best utilization after the computer becomes operational.
6. Senior staff can verify results directly via CRT's or from hard-copy printouts.
7. Worksheets are to be filed numerically after they are completed and are the only permanent records in the lab.
8. Results are accessible to doctors as soon as they are verified by the senior staff in lab.
9. Most patient reports are to be generated on stations. However, they may also be requested through the lab. Statistical reports and lists are printed in the lab as

required.

Summary Of Work Flow Improvements

1. The various stages for the processing of specimens are clearly monitored by the system via the 'status' and 'dates/times' indicators.
2. Any data entry by each person can be traced and identified from the system if required.
3. With computer-controlled test requesting, the number of duplicate specimens and invalid requests may be reduced substantially.
4. The system is able to assist in the processing of specimens in lab by providing the necessary information and the types of media required on the ID-labels.
5. One is able to standardize the reporting of microbiology results to some extent and to control errors in reporting.
6. Overdue cultures can be easily detected with the Overdue List.
7. The process of typing up reports is eliminated and thus one does not need to check typed-reports.
8. Workload statistics are tallied automatically. This should be useful in the overall management of the laboratory.
9. Delay in report delivery is reduced substantially by having patient reports printed directly at the nursing stations.
10. Manual filing of patient reports is completely

eliminated. Most data can be retrieved & reviewed at any time via the CRT.

11. Problems associated with delays in processing specimens can be analyzed by comparing the requested, collected, and received dates/times recorded in the system.

E. FORWARD PLANS

Strategies For System Development

1. The Microbiology Dept should provide at least one individual to assist in the initial development, implementation, and the testing of the system. This person should be relieved from the routine work during this period.
2. During the development phase, plans should be drawn for the necessary renovations and physical implementation of the computer hardware. This should be the responsibility of the liaison officer, the Directors of the Microbiology Dept, and the Computing Services Dept.
3. When the system is developed, the liaison officer should provide adequate testing to all aspects of the system to ensure its accuracy before and during implementation.
4. When the system is considered adequate by both the liaison officer and the Computing Services Dept, a parallel run should be scheduled accordingly.
5. The laboratory staff should be given adequate training prior to the parallel testing of the system.
6. During the first part of the parallel run, all requests

should still be on the manual requisitions and they have to be entered into the system by the lab staff. Results can be entered into the computer at this time. However, reports that are generated are viewed by senior staff only and not sent to the stations.

7. When the lab staff are familiar with the system, then the reports can be sent to the stations. At this stage, requests from nursing stations should still be on manual requisitions.
8. Nursing staff should be given training sessions on the use of the CRT's. When they are ready, the second stage of the parallel run can begin - the nursing staff can begin requesting tests directly from the CRT's.
9. If no further problems arise from the nursing stations during this parallel run period, the system is considered fully computerized. At that time, the Microbiology Dept will issue the letter of acceptance of the system.
10. Complete documentation should be prepared during all phases. They should be reviewed periodically by other senior members in the Microbiology Dept and the Computing Services Dept to ensure their accuracy and clarity.
11. Post-implementation evaluations are strongly suggested in order to measure the system's performance.

Considerations For Post-Implementation Developments

1. Billing of out-of-province patients, and patients with

no Alberta Health Care coverage, etc., should be reviewed and computerized if possible.

2. The system should be further developed to facilitate direct on-line entry of results, and move toward a no-paper system (i.e. no worksheets). This would require more data storage for the biochemical identification tests and more CRT terminals.
3. The system should eventually be expanded to play a major role in Infection Control Surveillance in the hospital.
4. The role of the system in its management functions in the laboratory should be further explored.

VI. DISCUSSION

A. FUTURE DIRECTIONS

The establishment of a computer-based patient information system for the clinical microbiology laboratory still remains as a great challenge among the efforts to computerize clinical laboratories. Many related aspects still await resolutions or clarifications. For example, the current use of various modes of data entry is a clear indication of the lack of general consensus as to the best mode to enter microbiology data. At present, standardization of such schemes seems highly unlikely and unrealistic, since there is wide variation in the types of laboratory computer systems in use. In addition, the coding conventions used in microbiology computer systems are often chosen on an arbitrary basis and this precludes the possibility of transmission of such data between systems (and thus restricts effective communications of patient information across institutions). Although standard coding schemes, such as the SNOMED coding system, have been available for quite some time, they have not yet been widely adopted due to the inability of many of the systems to handle these coding standards. Finally, the configuration of many of the existing systems and their data structures have severely limited the development of any standardized programs for statistical comparisons and evaluations on the accumulated data between systems.

Nonetheless, vast potentials still exist and remain to be explored in utilizing the computer more effectively to increase the overall efficiency and performance of the clinical microbiology laboratory. The range of such conceivable applications is limited, in part, by cost. Some of the areas that deserve particular attention are discussed as follows:

Computerized Quality Control Assurance

The computer should eventually assume a major role in ensuring the accuracy and correctness of all microbiology test results. With a set of clearly defined guidelines, the computer can automatically scrutinize test results for unlikely identification and sensitivity patterns, verify test results that appear acceptable, and bring to the microbiologist's attention only those results that are considered significant or require verification or further investigation. This can undoubtedly reduce the burden on senior technologists who otherwise would have to verify all test results manually. Furthermore, the inclusion of some form of computer-assisted organism identification routines, such as the one described by Kunz (1976), can greatly enhance the accuracy in the identification of various organisms, and can also serve as a continuous teaching and educational tool for the microbiology technologists. However, because of the complexity involved, great caution and care must be exercised in the development and testing of these routines, so that there will be no chance of erroneous

interpretations.

Direct Data Acquisition By Computer

Although most of the computerized microbiology reporting systems described in literature can be considered as on-line systems, a majority of these systems are not truly interactive in that their results are not entered into the computer immediately when they are obtained. Rather, most of the microbiology culture observations and test results are first recorded on some type of worksheets, which are then collected and processed in batches. Such a data entry method not only slows the rate of transmission of information, but also constitutes a weak link in the human-machine interface, since the accuracy of such data is subject to, and dependent on, human transcription from the worksheets after the actual test material is no longer available. Hence, it is highly desirable that such information should instead be entered directly into the computer at the time the test result is determined.

However, up until now, there has been little progress in this regard, since the elimination of the worksheet would mean that all microbiology results, including initial colonial and microscopic observations, biochemical identification tests, etc., would have to be stored in the computer, in addition to the organism and sensitivity results that are to be reported. Such propositions not only require tremendous amount of additional processing and storage, but can also contribute significantly to the

already-complicated logic and programs within the computer system.

Despite the immensity of such tasks, such endeavors do have much to gain. A system of such kind can easily eliminate duplications that are inherent in the worksheet routine, and increase significantly the degree of accuracy and control over the information so processed. With the cost of computer hardware rapidly decreasing, one should be able to expand the microbiology computer system, with relatively little additional cost, to assume a central role in direct acquisition of all microbiology data. The recent introduction of distributed and network processing into the clinical laboratories (Graham 1979) has also provided the prospect of processing all result entries at a local or peripheral level and passing on to a central computer only those results that are considered relevant. Such techniques can relieve the central computer much of the data processing that can be regarded as peripheral, and at the same time allow users a greater control on the entry of information at a local level.

Interface for Automated Instruments

Recently, various types of highly sophisticated and automated instruments that offer rapid bacterial identification and susceptibility testing capabilities are being introduced to the clinical microbiology laboratory by commercial vendors. Examples include the Bactec system from Johnston Laboratories, Inc., the Autobac-1 from Pfizer

Diagnostic Division, Differential III from Science Spectrum Inc., AMS from Vitek Systems Inc., MS-2 from Abbotts Laboratories Diagnostics, and the MiscroScan system from Scientific Products Inc., etc.[8]. Most of these instruments offer rapid direct detection and enumeration of pathogenic bacteria from clinical fluid specimens, and allow quantitative and/or qualitative antibiotic susceptibility testing of most non-fastidious pathogens encountered in clinical sources with only minimal human intervention. In particular, some of these instruments, such as the AMS, MS-2, and MicroScan, etc., are available as complete reporting systems that contain a mini or micro-computer module for managing the storage and reporting of microbiology test restults, as an addition to the components required for performing the microbiological analysis. At present, Vitek Systems Inc. (manufacturers of the AMS) are also developing a data management computer module to be included in their system that will allow generation of cumulative patient reports, bacterial susceptibility and biotype profile reports, and various epidemiologiy reports, etc., thus making the AMS a truly stand-alone and dedicated microbiology reporting system. In order to compete in this potentially profitable market, one can be reasonably certain that other commercial vendors will soon follow with similar computerized facilities for their automated instruments.

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[8]An extensive review of these systems is provided by Lorraine S. Gall and William A. Curby. See reference

It is important that these automated systems be evaluated as to their interfacing capability to various laboratory computers. This is especially critical for those microbiology laboratories that have already computerized, and those that are in the process of implementing a computerized microbiology information system. A few of the commercial vendors do provide some type of interfacing modules that allow direct transmission of data to an external computer unit. For example, the AMS offers, as an option, a serial interface device that provides asynchronous serial transmission of data that is generated from the AMS module. The data transmitted conforms to the industry standard RS-232C serial interface specification and the receiving computer merely has to generate a response to acknowledge the receipt of each block of data[9].

In general, there are few technological problems associated with making these interfaces. The recent introduction of microprocessors and micro-computers has made the task of interfacing much simplier, since one can use these micro-computers to act as code converters between two systems without having to convert the coding of programs in either of the two primary systems. However, despite this theoretical case, it usually requires a considerable amount of time and effort to make two systems uniform enough to communicate with each other. Therefore, great caution must be exercised in the purchase of any of these automated

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[9]Information obtained from AMS description brochure distributed by Vitek Systems Inc. Hazelwood, Missouri.

systems.

Computer-assisted Laboratory Management

Since the advent of the computer technology, much attention has been focused on its application to the business environment, especially in the areas of accounting, inventory control, fiscal planning and management. The microbiology laboratory also requires a great deal of control to ensure the effective utilization and planning of its resources. However, so far, most developmental efforts in clinical microbiology computer systems have been oriented towards the processing of patient result data, with little emphasis yet on computer-assisted laboratory administration.

Fortunately, much of the expertise is already at hand in this regard. So, when the more basic needs are met, there should be no great difficulty in applying computer-techniques to assist in the management of the microbiology laboratory. With adequate planning and programming, the computer can be used to tally workload statistics, monitor inventories and supplies, prepare budget reports, and possibly even to perform fiscal forecasts, etc., with minimum amount of human effort.

B. CONCLUDING REMARKS

Many laboratory computer systems are found to be inadequate or unsatisfactory only after their implementation. Indeed, such failures are not only confined to clinical laboratories. However, because of the high level

of sophistication and the high initial costs that are involved in the development of laboratory computer systems, the consequences of such occurrences can be especially catastrophic and costly. Thus great care must be taken in the initial planning of such a computer system. Some of the factors that should be taken into serious consideration include the following:

Adequate Planning

One cannot over-emphasize the importance of a well-consolidated plan prior to the development of a microbiology laboratory system. As in the initiation of any computer system project, a great deal of effort must be exercised in identifying the specific problem areas and defining the exact objectives of the proposed computer system. All too often computer systems are blamed for their inability to perform upto expectations. Frequently upon closer scrutiny, the real difficulty is found to be the lack of clearly defined system objectives.

Hence, with the proposal that is presented in this thesis, which includes various well-defined, concise system objectives and functional requirements, it is hoped that the potential for confusion and unrealistic expectations during the development and implementation of this particular proposed system has been reduced substantially.

Effective Communications

Close communication is needed between the microbiologists and the computing experts prior to the

development of a microbiology computer system. Because of the great degree of complexity involved in the microbiology laboratory, computing experts often fail to perceive the significance of various aspects within this particular area as a whole. Therefore, constant dialoque among the two are essential if a satisfactory computer system is to ensue. This level of communication should be extended throughout the entire course of the project, which includes the design, development, testing and implementation of the system. The laboratory staff should also be kept informed of progress and be familiarized with various aspects of the system, so that the degree of alienation that might occur during the introduction of the computer system can be reduced substantially.

On the other front, it should also be the responsibility of the microbiologist to establish close links with the medical and nursing staff in order to derive the best means for which the microbiology computer system can render its service. After all, one of the main purposes of the system is to act as a repository of microbiology data for use by the medical and nursing staff, who are the ultimate users of the system. Thus if the system is to be received enthusiastically and to operate successfully, approval and co-operation from the medical and nursing staff must be obtained at the earliest stages.

Long-term Committment

Rather than viewing the successful implementation of a

computerized microbiology information system as an end within itself, the computer system should be regarded as a tool whereby further improvements and expansions can be fulfilled. Despite the seemingly high initial costs involved in the implementation of laboratory computer systems, the present era is an age of research, development and expansion of this newly recognized technology, with the full spectrum of its potential benefits not yet realized. But clearly, the trend toward computerization in the clinical microbiology laboratories is evident.

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